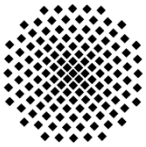

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Master's Thesis

Green Infrastructure Planning in Developing Countries; Developing Green Concept in Kurdistan Region-Iraq

Author

Mohamed Sawsan

Date of Submission

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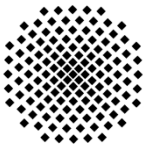

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JANUARY 4th, 2011

Submitted to:

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Erklärung des Autors

Hiermit erkläre ich, dass ich die vorliegende Arbeit selbständig verfasst und keine anderen als die angegebenen Hilfsmittel verwendet habe.

Author's Statement

I hereby certify that I have prepared this Master's Thesis independently, and that only those sources, aides and advisors that are duly noted herein have been used and / or consulted.

Date: **04. 01. 2011**

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Abstract

Under the shadow of 'Climate Change' and 'Global Warming' effects and within the arising interest to sustainable development, this document presents the long-term framework for sustainable development, protecting the natural and historic environment and adapting cities to climate change through Green Infrastructure Planning (GIP).

At the national level, the effect of climate change is overheating, with a more frequent sand storm, and major problem of water sacristy and drought. The Case Study Area is particularly vulnerable to, temperature increase, flooding, and to some extent drought conditions. Policies cover climate change mitigation and adaptation are various, starting from natural resource management, economic development, transportation plan, Green Infrastructure plan up to change of individual behavior regarding energy consumption. In the course of the thesis framework, Climate Change adaptation is limited to Green Infrastructure application as an integral and important practice of the development process.

Green Infrastructure Planning approach is an integration of planning at a different spatial level, so mainly two different special levels define the working environment, namely regional and metropolitan level. Also, Green Infrastructure provides a variety of ecosystem benefits. In the course of this study, the focus is on a certain function related to climatic, engineering and ecological benefits that will be used as the basic principal in developing the Green Infrastructure Plan at both Regional and City scale.

The proposed GI Plan for Case Study Region (CSR) is an academic initiative at Regional level to identify and safeguard valued natural and cultural resources. The plan aims to bring together the region's most important biodiversity areas, historical sites, and natural landscape including natural systems such as streams, Karez, watersheds, scenic landscape, and recreational site and to lesser extent working landscapes.

In a dense conurbation like the Case Study City (CSC) where green spaces have to be multi-functional, the green infrastructure refers to the network of all green spaces that provides various benefits to the residents. Therefore the proposed GI Plan for Sulaimaniyah City (CSC) is an academic initiative at the municipal level to identify valued community green space resources. The plan aims to bring together the city most important green space resources with development of a new typology. With the provision of providing better climatic engineering function in and around the existing City, to improve the current climatic condition and as an adaptation strategy for climate change effects.

So it is an initiative aiming to contribute to change the traditional conceptual understanding of green resource from something good to have, to an essential multifunctional resource that must be planned and developed in an integrated way.

Key Words: Green Infrastructure Planning (GIP); Green Infrastructure typology; ecosystem services; climatic engineering function; Core and Corridor.

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List of Abbreviations

°C: Celsius Degree

2D and 3D: 2 or 3 Dimensions

ANGSt: Accessible Natural Green space Targets

ANGST+: Accessible Natural Green space Standard Plus

B.C: Before Christ

B.P: Before present

B: Bottom

CAIT: Climate Analysis Indicators Tool

CBD: Central Business District

CGCM: Combination Generator Control Module 'Power & Energy Management Hardware'

CH_4: Methane

CN: Curve No.

CO_2: Carbon Dioxide

CPA: Coalition Provisional Authority

CS: Conservation Significant

CSC: Case Study City

CSR: Case Study Region

E: East

ECHAM4: Climate Model Software

ECOTEC: Emissions Control Optimisation TEChnology

E_Street Tree: Existing Street Tree

EPA: U.S. Environmental Protection Agency

EPI: Environmental Performance Index

FAO: Food and Agriculture Organization of the United Nation

GCM: General Circulation Model (general climate model),

GDP: Gross Domestic Product

GEC: Global Environmental Change

GFDL-R15: Climate Model Software

GHG: Green House Gas

GI: Green Infrastructure

GIP: Green Infrastructure Planning

GIS: Geographical Information System

Ha: hectare

HadCM2: Climate Model Software

HFCs: Hydrofluorocarbons

HLC: Historic Landscape Characterization

IAU: Inter-Agency Information and Analysis Unit

IGCO: Iraq German Cooperation

IMT: Individual Motorized Traffic

IPCC: Intergovernmental Panel on Climate Change

IS92a: IPCC Emissions scenarios on GHG effect in 1992.

ISA: Impervious Surface Area

JM-V, 98P-T: German standard for base load emission

JM-Z: German standard for base load emission

KBA: Key Biodiversity Area

Km: kilometer

KR: Kurdistan Region

KRG: Kurdistan Region Government

L: Left

LE: Latent heat

LULUCF: Land Use, Land-Use Change and Forestry

m: Meter

M: Middle

MlusEeg: Emission Modeling Software

MoCH: Ministry of Construction and Housing

MODIS: Moderate Resolution Imaging Spectroradiometer

MoEN: Ministry of Environment

MoWR: Iraqi Ministry of Water Resources

MtC: Metric Ton Carbon

N: North

NDVI: Natural Derived Vegetation Index

Nec_Link: Necessary Link

NGA: National Geospatial Agency

NI: Nature Iraq

NOx: Nitrogen oxides

OCHA: United Nations Office for the Coordination of Humanitarian Affairs

P: Precipitation

PAN: Peroxiacetylnitrate

PECADs: Production Estimates and Crop Assessment Division

PFCs: Perfluorinated compounds

PIU: Principles of Intelligent Urbanism

PM10: Particulate Matter

PMZ: Phyto Measurement Number

Pop. Density: Population Density

P-Street Tree: Planned Street Tree

R: Right

S: South

SF_6: Sulfur hexafluoride

T max: Maximum Temperature

T: Top

Tcpa: Town and Country Planning Association

UNDP: United Nations Development Program

UNESCO: United Nations Educational, Scientific and Cultural Organization

UNFCCC: United Nations Framework Convention on Climate Change

UNFPA: United Nations Population Fund

USDA: United State Department of Agriculture

UV rays: Ultraviolet rays

W: West

WFP: World Food Program

WGII: Working Group II

WWII: World War II

1 Introduction

1.1. Background

Greenery is more important now that it ever was. Greenery "are increasingly regarded as critical in providing ecosystem services of value for human health and wellbeing" [1] such as "mitigation of air pollution, noise, and heat, and provision of space for recreation and education"[2]. In the shadow of rapid expansion of urban areas conversion of land cover, systemic issues like urban heat island effect and global warming problems. Greenery with the modern understanding of ecosystems and biodiversity is the improvement of life quality more than their conventional aesthetic appeal. Urban greenery is also becoming increasingly accepted that they contribute to the sustainability of regions and cities.

The growth rate of world's urban population was rapid (from 220 million to 2.8 billion) in the past century. Urban inhabitants of Africa and Asia will increase by twofold; consequently, the accumulated urban growth through the historical time span will be duplicated in a between 2000 and 2030. The urban inhabitants of the developing world will constitute 81% of urban citizens up to 2030. The built space growth rate is more than the urban population growth. Between 2000 and 2030, It is predicted that the world's urban population to growth by 72%, whereas the built-up footprint of cities (of 100,000 inhabitants) might increase by 175%. That is why the future of humanity and cities mainly in developing countries, depends highly on present decision making to accommodate population growth. [3]

The newest scientific evidence confirms that global warming is the utmost threat to living and built environment and quality of life. In the consequences of climate changes, the increase in earth's surface temperature by 0.74 ^{0}C in the last hundreds of years has disturbed living ecosystems to force substantial risks on human wellbeing. The continuation or acceleration of this trend is predicted by climatologists, the earth's temperature might increase 4 ^{0}C to 6 ^{0}C by 2100, with expected disastrous impact on the natural environment, ecosystems and socio-economic security of earth's inhabitants. The co-effect of rapid urban growth and the impacts of changing climate will possibly have potent consequences on "environmental health in the tropics (causing, for example, heat stress and the buildup of troposphere ozone)" that may affect the social organization and urban economy. [3]

The burden and stress that human civilization put on the earth planet have been accumulated, and it is in incremental trend. This goes hand in hand with a human activity which is changing and shifting the natural ecosystem and imposing the humankind dominated ecosystem. Thus human-related ecosystem characterized by a significant change from the original one, now a day planner facing challenges in harmonizing this dramatic change. Their attempt is to lessen the negative impact on surrounding natural environment and bringing back nature to the buildup area. Consequently, it is logical to adopt the regional and urban development practices to force precautious and adaptive planning strategies in the aim of achieving environmental protection.

[1] Millennium Ecosystem Assessment. 2005. *Millennium ecosystem assessment: biodiversity synthesis.*

[2] Bolund, P. & Hunhammar, S. (1999) *Ecosystem Services in Urban Areas. Ecological Economics*,http://www.mistra.org/download/18.61632b5e117dec92f47800074424/Bolund+and+Hunhammar+1999+Ecosystem+services+in+urban+areas.pdf

[3] UNFPA (2008) State of world population 2007: unleashing the potential of urban growth, www.unfpa.org/swp/2007/english/chapter_3/index.html, [viewed on 6/06/2010].

In the current time with rising serious effect of climate change and global warming, a different strategy for mitigation and adaptation to this change are under research and implementation. As a consequence, the urban climate particularly and earth planet is in a critical pass. Although the urban climatic and air quality condition is are not entirely dependent on natural conditions, but also to a large extent on the spatial distribution of land uses, built structure and physical arrangement of development. With the increasing pressure due to human activity at the local level and climate change in the global level, the urban climate is an important and urgent issue to deal with. Although Planning-Related Urban Climate is not an extensively practiced strategy, "Since a universally accepted appraisal of climate does not exist, it is difficult to judge whether climatic incompatibilities can be expected to result from a planning process", but the global concern of climate change will give a significant shift in the degree of its importance. [4]

The climate change effect is predicted to increase the problem of water scarcity, desertification, drought, temperature increase and deforestation in Iraq. Also, urbanization is in incremental trend due to the rapid growth rate (2.63 to 3%) [5] and political state of the country. Regardless of the global and urbanization effects, the local situation of the study area is of major effect and concern. Several decades of war plus international sanction have caused severe damage to the environmental and ecosystem condition in Iraq, leaving the country with many environmental problems.

The recent emergence of environmental sustainability as a 'critical policy focus across the world', has been highlighted with climate change. "While a great deal of attention has recently been focused on climate change, other issues including water quality and availability, air pollution, deforestation and land use changes, biodiversity, and the sustainability of agriculture and fisheries have also gained prominence on the public agenda." [6]

The Case Study Region (CSR) is a remarkable demonstration of the interactive relation between built structure, climate and reliance on the water resources availability. It has an important footprint concerning resource management particularly watershed management, ecological and agro-ecological, biodiversity and wildlife in comparison to the rest part of the country. Never the less under the climate change potent CSR will be affected more if the counter measures have not been taken in this stage at the same time this footprint is becoming more important at both levels that urges the demand for a green infrastructure strategic plan.

It is agreed on that "fragmentation and isolation of green spaces leads to a loss of ecosystem services". [7] Built structure is to be panned and designed as a connected networks linking residential structure to build and natural open spaces and green corridors. Also, urban landscape planning is to be centered and conceptualized on multi-functional green infrastructure (GI) principal, which can assist flexible respond of an urban area to environmental challenges, including climate change. [8] The steady increase of urban temperature is due to systemic issues and global warming in CSC. This will be accelerated by the severe reduction of the green area in CSC. Thus environment quality is decidedly determined by land use planning. Green infrastructure planning at the municipal level is used as a decision support means to enhance climate mitigation, adaptation and protection, air quality preservation and surface runoff management.

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[4] Ministry of Economy Baden-Württemberg in cooperation with Environmental Protection Department of Stuttgart. (2008). *Climate Booklet for Urban Development Online – Städtebauliche Klimafibel Online. Indications for Urban land-use Planning*.

[5] United Nations (UN) (2008) *World Population Prospects: Population Division the 2008 Revision Population Database*, http://esa.un.org/unpp, [viewed on 30/06/ 2010].

[6] Lélé, S. H. (1991). *Sustainable development: A critical review*. http://www.sciencedirect.com/science, [viewed on 24/09/2010].

[7] Schwartz, M. W., editor. 1997. *Conservation in highly fragmented landscapes.*

[8] Gill, S.E., Handley, J.F., Ennosb, A.R., Pauleit, S., Theuray, N. & Lindley, S.J. (2008) *Characterising the Urban Environment of UK Cities and Towns: A Template for Landscape Planning*. Landscape and Urban Planning 87. www.elsevier.come/locate/landurbplan.

Regardless of conceptual problems, “the green dimension” must have the complete consideration to face these global and local challenges. The sustainable development concept indicates solidarity with future generations, plus several environmental welfares are problematic to attain in a short time period. The adaptation and mitigation stratify `preserving natural areas, reducing energy consumption, enhancing biodiversity, protecting forest, protecting watershed area and reversing climate change` are all importantly valued, nevertheless they are vital for the wellbeing of present and future generations.

1.2. Problem Statements

Due to the preceding war and internal political conflict, thus in addition to climate change effect, the CSR is facing the environmental problems, desertification, deforestation and decrease of green areas, thus regardless of uncontrolled industrial activity in the study area. The deforestation problem due to natural and manmade effects affected negatively the enhancement of watershed area and cause soil erosion at a certain part. The effect of climate change is more likely affecting biodiversity resource and wildlife as well particularly at the south-east (SE) part of the CSR, in addition to fragmentation of naturally reach biodiversity areas through human intervention. Generally, due to lack and weak preservation and conservation policy, the natural and cultural heritage of the CSR is at potential risk.

Although the regional performance of CSC is qualified as good regarding urban compactness but the urban ecological performance and particularly climatic one are regarded poor. The CSC has a lot of systemic issues like urban heat island, and trapping of air pollutant. Today, the urban area is facing environmental problems due to excessive population and high urbanization rate of 1.7%[9] this in addition to the burden of unplanned economic growth, industrial development, and automotive emissions. This caused a substantial increase of pollutants, affecting air, water, and land. The incremental rater of air pollution is rapid in CSC, especially due to vehicular traffic and geomorphologic setting of CSC that lies in the basin surrounded by mountain. The phenomenon of dust pollution together with the increase of air pollution is causing a dramatic condition that affects public health.

Over the years urban growth has caused a diminution of open spaces and green areas in and around the CSC, which causes various environmental problems. Since CSC is located in the heart of fertile agricultural areas; urban expansion evidently reduces the surrounding productive land. The percent of green space is far below the required range in CSC, as estimated by less than 3%. This can be due to the lake of landscape planning and spatial and institutional integration, since there is no well-structured planning hierarchy and planning approach is “bottom-up” decentralized approach.

The severe environmental problems with a combination of temperature increase and flood risk air pollution; this has had serious health and economical consequences. This should be dealt with as an urgent situation, the planner and the government should act not just to provide a higher quality of life but to prevent health catastrophe that may occur due to the current situation.

[9] Central Intelligence Agency (CIA) (2010) *The world fact book: Middle East Iraq.* https://www.cia.gov/library/publications/the-world-factbook/geos/iz.html accessed on 18-9-2010.

1.3. Objectives of the Study

1.3.1. Over all objectives

The overall objective of this investigation is to analyze the existing potential 'Green Infrastructure' and natural and cultural resources at both spatial levels 'Regional and City level', also to shed light on the climatic and systemic issues of CSC. Moreover to give an overview of climate change effect at national, regional and city level is an essential step. It will also look at strategic aspect and necessary measures regarding different potential and deficiencies.

The aim is to change the traditional conceptual understanding of "the green dimension" as mean to provide pleasant city but rather as resource management policy and as an adaptation mean to reverse and reduce the climate change and urbanization effect. Finally, the Green concept (with identified hierarchy of green typology) at both levels is developed to improve the microclimate condition, in the aim of contribution in the framework concept of global environmental change (GEC). Since GEC is the sum of a range of local, regional or national environmental challenges and contribution at any level is of great significance.

1.3.2. Specific Objectives

The specific objectives of this investigation are:

- To have a comprehensive overview on the basic concept of the 'Green Infrastructure Planning'.
- To develop a database and maps of the existing 'Green Infrastructure'.
- To carry out a situational analysis of 'Green Infrastructure 'in the CSR and CSC (concerning quantity, quality and connectivity).
- To determine and answer the question of 'which typology' of green area and 'where' to be located.
- To develop 'Green Infrastructure Plan' at the different spatial level that will be affected by the degree of emphasis on different ecosystem functions.
- To evaluate the proposed plan by developing a comparable base for ecological performance of the CSC.
- To identify possible means and recommendations to put a strategy for managing the 'the green dimension' in the study area.

1.4. Thesis Framework

The framework in which this thesis had been illustrated is originated from different spectrum including academic background, spatial and temporal situation of the Case Study Area also the international interest towered environmental issue and the urge of GIP Concept.

Academically the Infrastructure planning and regional planning, in particular, their Green dimension will model the general framework of the study. Specifically the holistic approach of integrated planning reflected in the forces that shape human live, consequent impacts and attempt to deal comprehensively with the economy, ecology, society and individual dimensions. The spatial

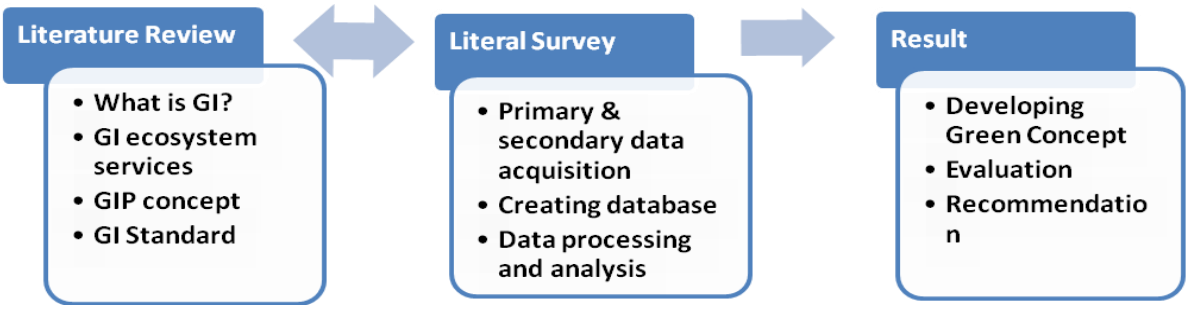
integration approach in planning will be reflected at different spatial levels of planning since physical linkages lie at the heart of GI. Moreover, this concept reflected in integrating planning policy at a strategic and local level and joining up all related party. The most important application of integration is reflected in the integration of the Green Infrastructure Planning (GIP) with conventional landscape planning. While GIP represents the coming together of various environmental, economical and social interests "It is not seen just as a way of providing an improved green structure for the landscape, but also as a mechanism for more informed decision-making and more 'joined-up' thinking in relation to urban and regional environmental planning" [10]. The later (landscape planning) is providing a holistic approach to understand many processes, which "shape the land and potential changes to which a particular location could be subjected over time"[11]. Since the function of both are interrelated, and the cause of disturbance is the same which caused by human activity, the approach to integrate both will be adopted.

The national condition of the country particularly, and the Climate change at the global level made the CSA a controversial and important case to deal with. Due to the preceding war and high rate of growth, the country is facing a dramatic degradation of environmental condition and quality of life. That is why in this stage immediate intervention is necessary for which the primary aim should be human wellbeing and natural environment.

Finally the global condition particularly the Green House Gas effect and climate change phenomena that affect humanity and the environmental system of Earth planet seriously. The Millennium Ecosystem Assessment clearly demonstrated that the majority of our ecosystem services are being degraded and that drastic action, such as restoring natural capital, is required to ensure the long-term continued flow of these services.[12]The attempt to decrease and reverse those damage that causes from human activates starting from the industrialized era and continuing up to now, through different planning, adaptation and mitigation directive in developed countries. This lead to emerging focuses of international awareness to sustainability concept. In addition to a recent enthusiasm for pushing forward GIP indicates that "GI has become a 'muster point' for academic, public bodies and practical agencies interested in green space issues and a way to help develop environmental thinking across disciplinary and political boundaries" [13].

1.5. Work Flow

The scope of this investigation follows a traditional systematic approach of literal survey analysis and result interpretation. The data collection or literal survey process goes hand by hand with literature review; see Figure 1.1 illustrate a general framework of this study.



[10] Davies, C., MacFarlane, R., McGloin, C. & Roe, M. (2008) *Green Infrastructure Planning Guide, Version 1.1*. http://www.uwsp.edu/geo/faculty/gmartin/GEOG391/Lecture/GREEN_INFRASTRUCTURE_PLANNING_GUIDE.pdf

[11] Landscape Institute (2009); *Green infrastructure: connected and multifunctional landscapes*. Available at http://www.landscapeinstitute.org/.

[12] Millennium Ecosystem Assessment, *Ecosystems and Human Well-being: A Framework for Assessment*.

[13] Davies, C., MacFarlane, R., McGloin, C. & Roe, M. (2008) *Green Infrastructure Planning Guide, Version 1.1*.

Figure 1.1: Workflow of the study

Source: Author, 2010.

The thesis tackles specific case study at different spatial level as different stages unfold throughout the chapters. In this sense, the structure consists of seven main chapters necessary to accomplish the objectives of the study.

1.6. Overview of the Study Area

The scope of this study is limited to developing country Iraq – within administrative and geographical border of Kurdistan Region (KR) (Erbil, Sulaimaniyah and Dohuk) and also Kirkuk as the Case Study Region. The case study is conceder Sulaimaniyah City as a CSC with challenging environmental characteristic, in order to develop green concept.

1.6.1. National Context- Iraq

1.6.1.1. Location and Administrative Units

This section looks at the general characteristic at the national concept. It introduces the study area within its national through administrative and climatic context. Iraq is located at 33°20'N 44°33'E and has a total area of 437,072 km². It bordered by Jordan, Syria, Turkey, Iran, Kuwait and Saudi Arabia. 14 It has eighteen governorates (or provinces) which are further divided into districts (qadhas). The Kurdistan Region (KR) is the legally defined region within Iraq and has local government; Figure 1.2 shows the administrative state in Iraq.

Figure 1.2: Map of geographical and administrative border of Iraq and Kurdistan Region

Source: http://www.emro.who.int/iraq/pdf/ICMMS_Analysis.pdf

[14] Wikipedia, *Iraq Geography*, http://en.wikipedia.org/wiki/Iraq.

1.6.1.2. Demographic and Socio-Economic Characteristics

Iraq is a reinter state in which its economy is strongly dependent on oil and natural gas revenue, accounting for nearly 95% of the country's revenues from oil export. According the United States Department of Energy, Iraq has the world's second largest petroleum reserves (215 billion barrels). In the past, agricultural sector was the second largest after the oil sector, nevertheless due to Iraq preceding war and drought this sector had been damaged increasingly.

Iraq population is estimated currently at 31,467,000 inhabitants[15], with wide spectrum of ethnic and religious diversity. Iraq urbanization trend is increasing due to natural growth rate and urbanization. To give a general overview, see Table 1.1.

Table 1.1: Socio-economic profile of Iraq

Source: Author, 2010.

Profile	Value
Population growth rate	2.63%*
Urban population	67%**
Rate of urbanization annual	1.7%**
GDP per capita dollars	4,363**
Industrial production growth rate	3.1% (2009 est.) ***

*2008 UN estimate for year 2010 **https://www.cia.gov/library/publications/the-world-factbook/geos/iz.html .***Annual Statistical Bulletin,2009 P13, OPEC.

1.6.1.3. Geography and Climate

The country is predominately desert, but near the two major rivers (Euphrates and Tigris) are fertile alluvial plains.[16] It is fairly flat with mountains to the Northeastern part, (see Figure 1.3). The climate of Iraq is of semi-arid and hot-arid type, designated as continental, subtropical. The mountains in the north-east (NE) have cool summers and cold winters, while the plains and deserts have hot summers and short cool winters. Summer temperatures average above 40 C for most of the country and frequently exceed 48°C. Winter temperatures infrequently exceed 21 C with day time and night-time lows occasionally below freezing. "Typically precipitation is low; only about 150 mm in the central plains and even less in the desert. The mountains receive up to 380 mm, sometimes in the form of snow"[17] Rainfall during the summer is extremely rare, except in the far north (N) of the country. See Appendix B – Figure B.1, B.2 and B.3.

[15] United Nations (UN) (2008) *World Population Prospects: Population Division the 2008 Revision Population Database*, http://esa.un.org/unpp.
[16] Wikipedia, *Iraq Geography*, http://en.wikipedia.org/wiki/Iraq.
[17] Food and Agriculture Organization of the United Nation (FAO) (2009) *Iraq Geography, Climate and Population*.

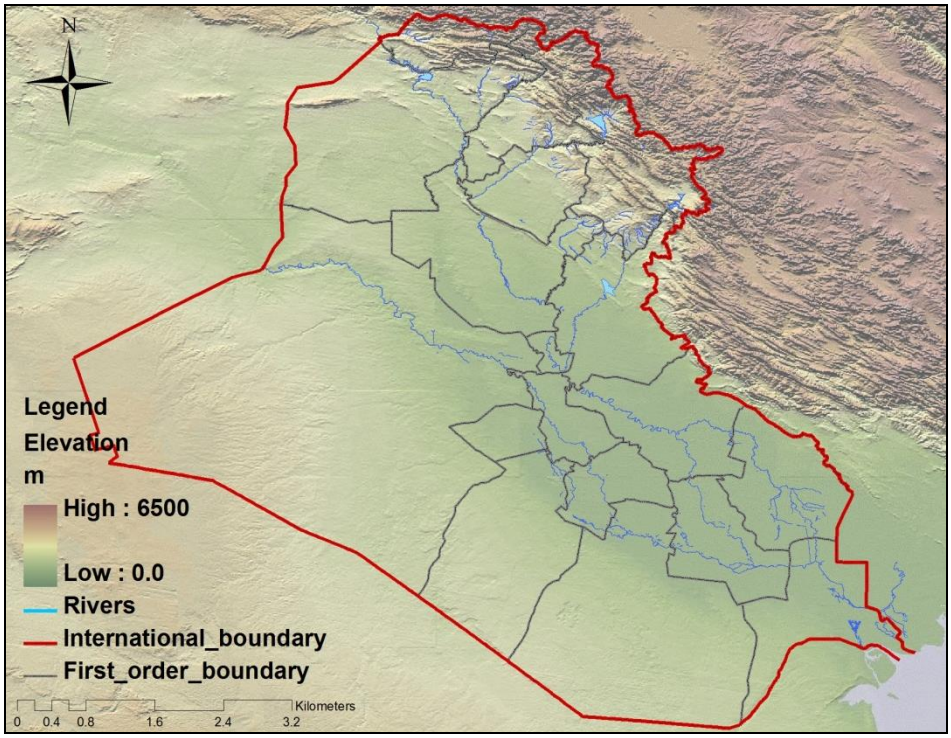


Figure 1.3: Iraq topographical map

Source: Author, 2010, from National Geospatial Agency (NGA) data.

1.6.1.4. Vegetation Cover

Iraq situated at the centre of the world's largest arid zone (the immense desert belt stretching across the African and Eurasian continents from the Atlantic Ocean to the Gobi Desert) is very lightly forested. Forest covers about 800 000 ha, or 1.8% of the country's area. Most of the forests in the mountain region in Iraq (KR) growing at altitudes of 700 to 1400 m above sea level. Iraq has been divided in to four main vegetation zones: **Desert zone**, with very little variety of plant species due to severity of climatic condition, **Steppe zone** with common vegetation type of small trees and shrubs. **Mountain forest zone** and **Alpine zone** are characterized by variety of plant and giant tree species, see Figure 1.4. [18]

Iraq is a largely desert country with a limited precipitation rate; only 13% of its land is arable. It is projected that around 11.5 million ha, which is about 26 % of the whole country area, are cultivable, however the total cultivated area is appraised by 9.45 million ha in 2007, of which nearly half is in north region under rainfed practices. Iraq has been distributed into four agro-ecological zones: "**Arid** and **Semi-arid zones** with a Mediterranean climate" with nine months growing season. Plains with winter rainfall of 200–400 mm yearly, feed barley production areas with limited irrigation, the "**Desert zone"**, with very few irrigated spot and "**Irrigated zone"** that covers the area between the Tigris and Euphrates rivers from the middle to the south (S) of country, with vegetable and rice production. [19]

[18] Food and Agriculture Organization of the United Nation (FAO) (2008) *Forestry Country Information, Iraq*, http://www.fao.org/forestry/country/18314/en/irq/.

[19] Food and Agriculture Organization of the United Nation (FAO) (2009) *Iraq Geography, Climate and Population*.

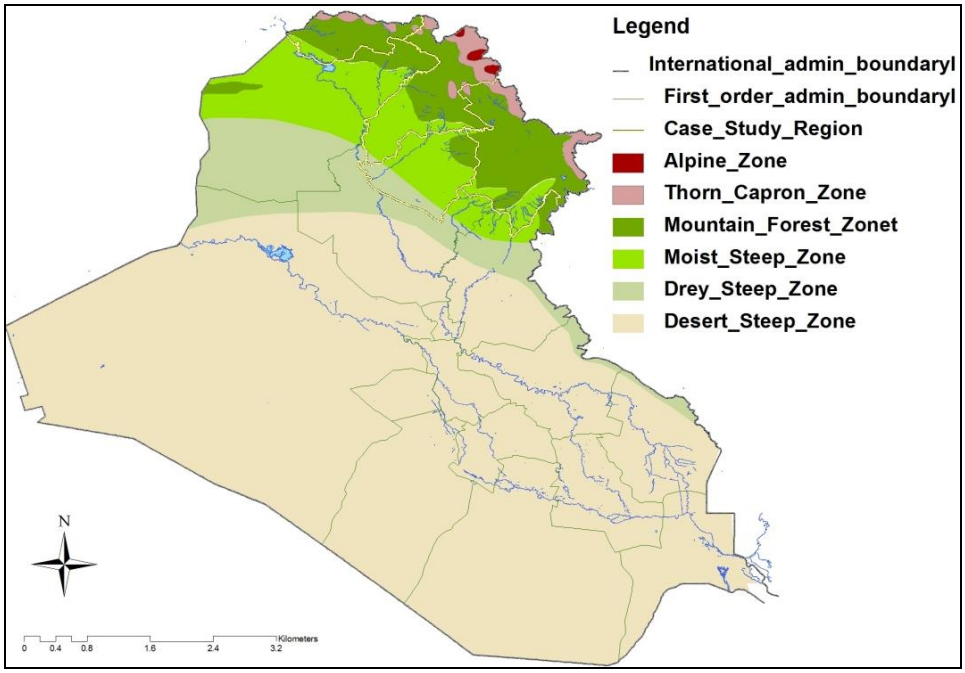


Figure 1.4: Iraq's vegetation zones

Source: Author, 2010, digitized from Chapman, 1957.

1.6.1.5. Climate Change Effect

Whereas lots of governments and non-governmental establishments have established plans to address climate mitigation or adaptation. Iraqi government did inconsiderable action regarding this topic. Some related international organization did some research about the effect of climate change in Middle East and Iraq. The effect of climate change in Iraq is varying, so the author depends on the different modeled data to illustrate the projected effects and highlight the recent climatic phenomena, and potential impacts.

Climate change projections for the 2020s, in the Middle East are compared by adopting simulation outcomes of four different models GCMs (ECHAM4, HadCM2, CGCM1, GFDL) with similar assumptions (IS92a scenario). The seasonal temperature change and the rainfall variation in the wet seasons are calculated by the different models, see Table 1.2.

Table 1.2: Projected climate change effect in Iraq for 2020

Source: Climate change parameters (IPCC-DCC 1999).

	Mean temperature increase (°C)				
	HadCM2	GFDL-R15	CGCM	Echam4	T max
January-March	0.9	1.7	1.6	1.1	1.7
June-August	0.9	2.1	1.5	1.5	2.1
	Mean rainfall change (mm/day)				
	HadCM2	GFDL-R15	CGCM	Echam4	P max
October-April	0	0	0	0	0

Note: Values are for 2020s relative to the 1961-1990 periods.

The results display no variations in mean precipitation, while temperature is expected to rise at a seasonal base, mean temperature will rise significantly by (0.9-2.1 °C). [20] Other climate model has anticipated 20-30% decrease in runoff in most of the Middle East region including Iraq by 2050. [21]

From projected modeling to the real climatic events, Iraq recently is having different and rare phenomenon. The dust, sand and snow storm that recently occurring more frequently and covering wider area of the country in a comparison last decades, see Appendix B – Figure B.3 for satellite images. The impact of drought and desertification is getting main focus. The lack of river discharge causes "ongoing soil erosion that leads to further desertification and increased heat and dust storms, which has a measurable negative impact on the quality of life of the Iraqis". Also Climate Institute in Washington mapped the desertification vulnerability and ranked Iraq as a high to very high vulnerable country to desertification. [22]

A potentially high impact was noted in terms of water quality and quantity. IPCC researches demonstrate that the Middle East region including Iraq has experienced augmented levels of drought (from 1990 to 2002) as compared to baseline period. It is projected that Middle East region to face the challenge of water shortage and poor quality by 2025. Due to the semi-arid weather of the Iraq, water resource pose a limitation on human welfare and development. This designates that possible wellbeing impacts might be considerable. Particularly Iraq, which depends severely on river flow from Turkey, might be highly affected since trans-boundary water flow is expected to decrease as Turkey recent wide development in hydrological projects (Dams). Accordingly the health effects of water resources vulnerability due to changing climate will occur as a result of augmented temperatures and decreased water resource. Due to more intense and frequent extreme weather events, crucial health consequences and augmented spread of diseases may occur seriouly. UNFCCC 2006 projected that "greater exposure to heat stress, vector-borne diseases such as malaria and water-borne diseases such as cholera." Both diseases are on the increasing trend in Iraq. [23]

"A general reduction in potential crop yields in most regions in mid-latitudes" is expected. [24] Drought gripped Iraq in different time interval the most recent were in 2007-2008 growing season, which affected the crop yield that mainly depends on rain fall and estimated by 38.7% decrease in a comparison to average level. In the analysis of natural derived vegetation index (NDVI) is observed the most affected area in Iraq, see Appendix B – Figure B.4.

The other extreme to above mentioned impacts is flood risk, since urban and rural population settled in the basins of the Tigris and Euphrates Rivers. Consequently, the floods in the river basins can lead to substantial socio-economic damages. Nonetheless, "flood risk in Iraq will be highly dependent on upstream control".[23] The socio-economic implication of climate change impacts of water sector is estimated by 3-6% of GDP reduction in Iraq. The most implication of climate change are not simply 'amenable to monetary valuation (IPCC-WGII 1997)'. The implications contain "loss of human life, loss of natural habitats, species loss, migration, and uneven resources distribution within a single country". [23]

[20] El-Fadel, M. & Bou-Zeid, E. (2001) *Climate Change and Water Resources in the Middle East: Vulnerability, Socio-Economic Impacts, and Adaptation*, http://papers.ssrn.com/abstract=278514.

[21] Evans, J. P. (2008). *Changes in Water Vapor Transport and the Production of Precipitation in the Eastern Fertile Crescent as a Result of Global Warming,*" Journal of Hydrometeorology.

[22] James Denselow, Huffington Post (2009). *Climate Change and Iraq***.** Posted: July 20, 2009 10:56 AM.

[23] El-Fadel, M. & Bou-Zeid, E. (2001) *Climate Change and Water Resources in the Middle East: Vulnerability, Socio-Economic Impacts, and Adaptation*.

[24] United Nations Framework Convention on Climate Change (UNFCCC) (2007) *Climate Change: Impact, Vulnerabilities and Adaptation in Developing Countries.*

1.6.1.6. Environmental Footprint

In a research "Pilot 2008 Environmental Performance Index" by Yale University and Columbia University they identified EPI for 163 countries with 24 indicators. The Environmental Performance Index (EPI) assesses two main objectives of environmental policy: "Environmental Health" that assesses environmental stresses to human health; and "Ecosystem Vitality" that assesses ecosystem health and natural resource management. Related indicators, like Environmental Burden of Disease, air pollution, water (weighted by 12.5%) and biodiversity, forestry, fisheries, agriculture and Climate Change (weighted by 25%) have been used. Iraq performed poorly and ranked as 150 and scored 41 points[25].

In a research by Christopher D. E. et al, spatial distribution and mass of built impervious surface area (ISA) have been presented for the years 2000-01 for top Hundred Countries. ISA comprise "roads, parking lots, buildings, driveways, sidewalks" and other built surfaces. For Iraq, ISA estimated as 1,785 km^2 at a country level and ISA per person estimated by 70.3 m^2 with an estimated population of 25,398,480 inhabitants (Landscan 2004). [26]

Purdue University made a research using Climate Analysis Indicators Tool (CAIT) in 2000. National GHG Emissions (CO_2, CH_4, N_2O, PFCs, HFCs, SF_6) for 2000, the global emissions for Land Use, Land-Use Change and Forestry (LULUCF) have been estimated. Iraq ranked as 56 with **27.6** MtC for total GHG emission and ranked as 46 with **27.5** MtC Emissions from non-LULUFC.[27]

1.6.2. Regional Context Kurdistan Region

1.6.2.1. Location and Administration

As mentioned earlier in section 1.6.1 the Kurdistan Region (KR) is the only federated region in Iraq. It cover approximately 40,000 km^2 and located between 32°57′N to 37°22′N and 41°17′E to 46°20′ E.
Erbil is the administrative capital of KR, so it is a hub of all governmental offices and foreign representation consulates; While Kirkuk Governorate is only within the geographical border of the KR with approximately 7792 km^2 in area (see Figure 1.5). [28].Each governorate consists of one main city (capital city) and two other smaller cities. Also every governorate administratively is divided into districts with a total of 26 districts. The district is divided into sub-districts, each with its own district-center.

[25] Yale Center for Environmental Law & Policy and Center for International Earth Science Information-Network (2008) *Pilot 2008 Environmental Performance Index*.
[26] Elvidge, C.D., Tuttle, B. T., Sutton, P.C., Baugh, K. E., Howard, A.T., Milesi, C., Bhaduri, B.L. & Nemani, R. (2007) *Global Distribution and Density of Constructed Impervious Surfaces*, http://www.mdpi.com/1424-8220/7/9/1962/pdf.
[27] Butler, R. (2010) *National Greenhouse Gas Emissions from Energy Use and Deforestation,* http://rainforests.mongabay.com/GHG_emissions.html
[28] Wikipedia, *KRG Geography*, http://en.wikipedia.org/wiki/Iraqi_Kurdistan.

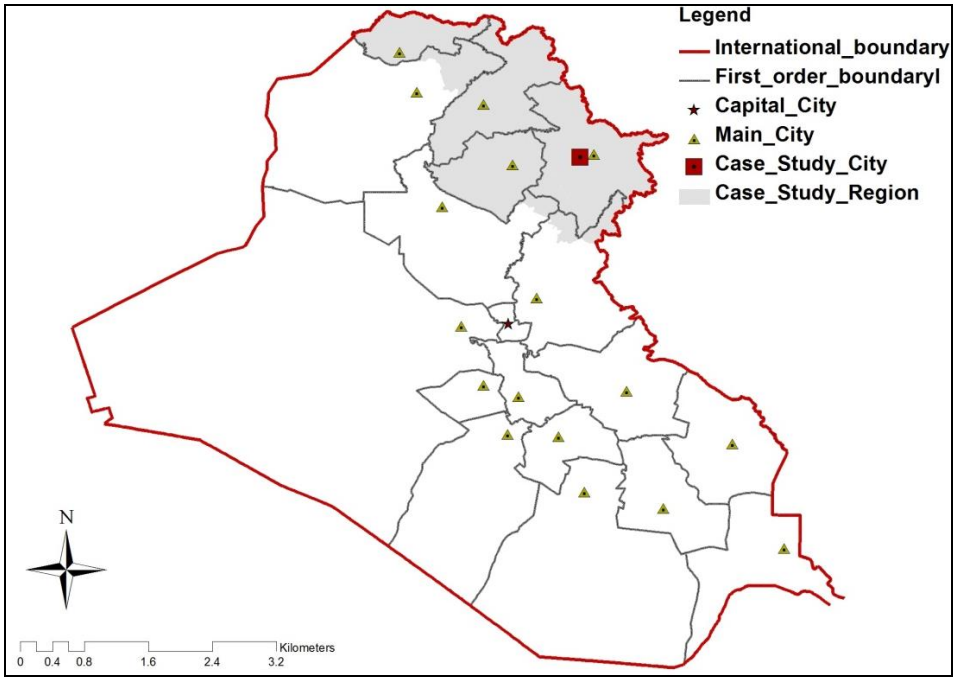


Figure 1.5: Map of the Case Study Region and Case Study City within national context

Source: Author, 2010.

1.6.2.2. Demographic and Socio-economic Characteristic

The Kurdistan Region has earned a good fame of peaceful life with wide spectrum of ethnic and religious diversity. Kirkuk city is known as a small Iraq, It consist of wide spectrum of different ethnic and religious groups like Arabs, Turcoman and Kurds. Due to the everlasting conflicts about this city and socio-demographic converting policy applied by Iraqi former government, the security of this city is not comparable to the one in KR, in the current state.

Since 1991, with the establishment of regional non-fly zone, and particularly latter since 2003, the Kurdistan Region has experienced rapid growth in deferent sectors. In 2004, the per capita income was 25% higher than in the rest of Iraq. [29] The economic growth scenario based on 9% per annum growth in Gross Domestic Product (GDP) this is higher compared by the 4% worldwide average GDP growth.[30]. The region have an economic development plan that focuses mainly on the international oil and gas market, in parallel to the revival of agricultural and tourism sectors, and enhancing other industrial activities, like cement. While Kirkuk city itself is located on the site of a historical settlement from 3000 B.C., which is a fertile land in a very rich oil-producing area. Kirkuk is the second richest oil city at a national level.

The population of KR for 2007 is estimated at 4,910,742 with an average natural growth rate of 2.2%, thus regardless of internal migration due to war and internal conflicts in addition to urbanization rate. In general around 50-60% of population is living in main capital cities with 11% in the rural areas and the rest are living in smaller cities (districts).[31] It is important to mention that Capital city population percent only include those population whom are officially registered by food

[29] Wikipedia, *KRG Geography*, http://en.wikipedia.org/wiki/Iraqi_Kurdistan.

[30] Ministry of Municipality and Tourism, Planning Dep. *Erbil City Master Plan, Final Master Plan Report by Dar Al-Handasah*.

[31] United Nations World Food Programme (WFP),(2008), *Comprehensive Food Security And Vulnerability Analysis In Iraq:* The *2008 Revision*, http://home.wfp.org/stellent/groups/public/documents/ena/wfp192521.pdf , p 137.

distribution directorate and the actual figure exceed by 3-8%. Urban population in Dohuk city is not within the same range as others is due to the influence of Zaxo city in the same governorate which is an economical hub with high population. The Table 1.3 shows the distribution of population in the study region.

Table 1.3: Spatio-demographic distribution of CSR

Source: Compiled by Author, 2010.

	Governorate Area square Km**	Governorate population 2007*	Capital city population*	Capital city population%
Dohuk	9,836	973,118	279,307	28.7%
Erbil	15,883	2,019,688	1,218,911	60.35%
Sulaimaniyah	14,924	1,917,936	831,495	43.36%
Kurdistan Region	40,643	4,910,742	2,329,713	47.45%
Kirkuk	7,792	902019***	572,080***	63.42%
Total CSR	48,435	5,812,761	2,901,793	49.9%

*Kurdistan Regional Statistical office, http://www.krso.net/ .**www.iauiraq.org *** http://home.wfp.org.

These statistics also reveal that 53.67 % of the governorate population is living in Sulaimaniyah district and 90.25 % of them in fact live in city of Sulaimaniyah." [32] Accordingly Capital city population percent will be 49.52%, with a difference of 2.7% this only representing official figures.

1.6.2.3. Geography and Climate

Following the geological formation of the CSR, `developed mountainous ranges', 'foothill pediments', and 'agricultural plains' forming the three major morphologic units. The climatic setting is various, from hot and dry plains to cooler mountainous areas. The mountainous area in KR is part of the Zagros range, with elevations exceeding 3000 m. The highest location being at 3,611 m level, that known locally as Cheekah Dar (black tent). Some of the mountains are more than 2500 m high while toward SE, their elevations decrease gradually and change to sporadic hills and sometimes plains at Kirkuk governorate. There are many rivers (Lesser Zab, Great Zab and Sirwan) flowing crossways the mountains to plains creating natural "fertile lands, plentiful water, picturesque landscape". The Tigris River enters Iraq from the KR.

According to the Koeppen classification scheme proposed by Critchfield, climate of the KR is classified as interior mediterranean, mild to cold winter, dry and hot summer and is symbolized by Csa. This in addition to small area at the very SE part of the KR, climate type is tropical steppe, semiarid, hot and symbolized by Bsh. [33] Typical semi-arid climate conditions are prevalent in the lower plains. In hot season, the CSR is under the influence of Mediterranean anticyclones and subtropical high pressure zone.

In winter, the CSR is dominated by Mediterranean cyclones moving from E to NE, this in addition to Arabian Sea cyclones moving toward N with high rate of moisture content that cause precipitation sufficient to support dry farming activities. The CSR is also influenced by very cold polar air mass. The mean wind speed is varying seasonally ranging from 2.5-1.8 m/s from summer to winter correspondingly. Also the direction of prevailing wind is varying from SW, S, W and SE.[34]

[32] Jalal, J. (2008) *Natural Resources and Its Utilization for Agricultural Development in Sulaimany Governorate*. PhD. Thesis
[33] Critchfield, H.J. (1974).General Climatology, 3rd edition.
[34] Ahmad, S.H.A. (2008) *Geographic analysis of the wind characteristic in the Iraqi Kurdistan Region and its Potential Exploitation*. Master Thesis.

The northern mountainous regions have cold winters with occasional heavy snows, sometimes causing extensive flooding. [35] Rainfall is seasonal and occurs from November to April, mean annual rainfall is ranges from 290 mm to 1 200 mm. "The rainfall is much higher than in the rest of Iraq and often well over 1,000 mm per year, including a considerable amount of snow during the winter" [36] . The four summer months from June to September are completely dry. Winters are cool, with a mean annual temperature ranges from nearly 12°C at the Iranian border to more than 22 °C. The mean minimum monthly temperature ranges from 0.2 °C for extreme N to about 3.5 °C for SE part of KR. While the mean maximum temperature ranges from 39 °C to 49 °C for respectively during July and August.

"The mean annual evaporation ranges from about 800 mm for N and NE to more than 250 mm for SE. The ratio of actual sunshine duration to the maximum possible sunshine duration ranges from 0.4 in January to nearly 1.0 during the summer months. The relative humidity ranges from about 30% in July to about 80% in January." [37]

1.6.3. City Context- Sulaimaniyah City

1.6.3.1. Administration and Location

Administratively the city of Sulaimaniyah is the capital of Sulaimaniyah Province (governorate), which is one of the three governorates in the KR. Sulaimaniyah governorate, includes the nine districts. Sulaimaniyah city is divided up into 77 quarters. The city is also referred to as: Al-Sulaimaniyah or Sulaimani in Arabic and English respectively. It has international border with Iran represent the eastern boundary of the governorate where, it is bound N and NW by Erbil governorate, W by Kirkuk governorate and Salahaddin governorate, and SW and S by Diala governorate.

1.6.3.2. Demographic and Socio-Economic Characteristic

The city's population is estimated as 831,495 inhabitants in 2009[38] with a growth rate of 2.2%. This growth can be attributed to the increasing security and economic development. The urbanization rate is not steady, and has a lot of fluctuation due to many factors which affected urban structure negatively.

The shift in population from the rural areas into the metropolitan city of Sulaimaniyah and other main towns was due to: The Iraqi- Kurdish conflict during 1961-1990 and the Iraqi-Iranian conflict during 1980-1988, also the creation of the prohibited mined boarder zone with Iran (320 km). The former government by a deliberate policy destructed 1500 villages in the territory that dropped the percentage of rural population for a half in a comparison to 1977s ratio. From 1991 up to 1998, remigrations started back to the villages, but the distribution of food program for oil in 1998 among other strategies by the governorate lead to massive migration to the CSC again. Overall the rural population has decrease over the years and the city and its metropolitan continued to grow though

[35]: Wikipedia, *KRG Geography*, http://en.wikipedia.org/wiki/Iraqi_Kurdistan.
[36] Kirk, A. & Sawdon, G. (2002) Understanding Kurdish Livelihoods in Northern Iraq: The household economy, understanding the situation of Kurdish livelihoods. Vol. 3 of 3, Final Report. UK: The Northern Iraq Country Programme and the Food Security and Livelihoods Unit-Save the Children (UK).
[37] Food and Agriculture Organization of the United Nation (FAO) (2009) *Iraq Geography, Climate and Population*. Rome: FAO, ftp://ftp.fao.org/docrep/fao/012/i0936e/i0936e08.pdf.
[38] Kurdistan Regional Statistical Office, *Population*, http://www.krso.net/,

not consistently. See Table 1.4 on the urbanization trends in the metropolitan region of the city and the rural areas.

Table 1.4: Urbanization trend in Sulaimaniyah City

Source: Compiled by Author, 2010.

	1977*	**1987***	**2000****
Metropolitan Population%	52.8%	71.5%	72.4%
Rural population %	47.2%	28.5%	22.6%

*Official censuses of 1977, 1987. **Ministry of Interior and defense, Sulaimani Department of Statistics.

Sulaimaniyah economy is based on small industry, farming, trade and tourism. Sulaimaniyah used to be a popular tourist destination among Iraqis escaping the summer heat of the plains (temperature up to 50^{o}C) to enjoy the relatively cooler climate. It is a growing city due to in-migration and returnees.

2 Literature Review

2.1 Principal System Theory

This section look at the basic theoretical approach that had been adopted by author to frame the general concept and main idea of the paper interrelated to the Case Study Cities (CSC). It is looking at the main philosophy behind the whole work.

2.1.1 Principles of Intelligent Urbanism (PIU)

It is a theory of urban planning composed of a set of ten axioms intended to guide the formulation of city plans. Specifically the first axiom "**balance with nature**" that is the basic philosophy of this paper, in which "emphasizes the distinction between utilizing resources and exploiting them. It focuses on the thresholds beyond which deforestation, soil erosion, aquifer depletion, siltation and flooding reinforce one another in urban development, saving or destroying life support systems. This principle states there is a level of human habitation intensity wherein the resources that are consumed will be replaced through the replenishing natural cycles of the seasons, creating environmental equilibrium".[39]

With intensive consumption, destruction and reversion like cutting of hillside trees, quarrying on slopes, dumping sewage into the natural drainage system, paving excessively, and construction on steep slopes. There will be point of no return; utilization of natural resources will outpace the natural ability of the eco-system to replenish itself. From there on degradation accelerates and amplifies. Deforestation, desertification, erosion, floods, fires and landslides all increase. This urban theory proposes that the urban ecological balance can be maintained when fragile areas are reserved, conservation of eco-systems is pursued, and low intensity habitation precincts are thoughtfully identified.[39]

2.1.2 Sustainable Development and Sustainable Community Concept

Sustainable development is a holistic concept that entails an interdisciplinary, system-based framework to contemplate social, economic, cultural and ecological aspects on several interactive spatio-temporal scales (Ulo Mander et al. 2007);[40] where GIP is the network of greeneries that provide multi social, economic and environmental benefits.

The President's Council on Sustainable Development described GI as a main strategic theme, which delivers a holistic method for sustainable community development. The Council reported that, "GI strategies actively seek to understand, leverage, and value the different ecological, social, and economic functions provided by natural systems in order to guide more efficient and sustainable land use and development patterns as well as protect ecosystems."[41] GI is becoming a pioneer in contemporary planning concept as well as described as a one of the pillars of eco-towns planning.

[39] Wikipedia, *Principles of Intelligent Urbanism*, http://en.wikipedia.org/wiki/Principles_of_Intelligent_Urbanism.

[40] Mander, Ü., Wiggering, H. & Helming, K. (2007) *Landscape Tomorrow: Multifunctional Land Use, Meeting Future Demands for Landscape Goods and Services*. P1, P37.

[41] The President's Council on Sustainable Development (1999) *Towards a Sustainable America. Advancing Prosperity, Opportunity, and a Healthy Environment for the 21st Century*.

"Eco-towns should maximize the GI contribution to resource management, leaving hard engineering solutions to make up any shortfall". [42]

Space is an essential aspect of human societies and "social justice" is embedded in it. Planners aim to reduce social injustice through providing good interaction between space and society. While this is directly related to special dedication and planning, that is strongly related to decision making process. Likewise in degree of importance is "environmental equity". The emergence of the sustainability theory has promoted the environmental equity argument. "It questions our ontological relationship to the world, and the possibility of a fair policy addressing the needs of mankind, present and future, local and global, and of new forms of governance". [43]

2.1.3 Multi-Functional Green Infrastructure

Landscapes are multi-functional via their instantaneous provision of 'habitat, productivity, regulatory, social, and economic functions'. Heterogeneity is a main feature of landscape and therefore, it signifies the ability of landscape to support several, occasionally contradictory functions concurrently. [44]

Landscapes are complex entities; dynamic in and of themselves and further complicated in the human dimension of how they are perceived. Each landscape is a function of abiotic and biotic prototype joined by landscape distinctive history of human intervention. Multifunctional landscapes are dynamic, self-organizing and non-disruptive structure. This is essential to halt and reverse declining trends in the majority of ecosystem services. Furthermore a landscape that assists species adaptation to climate carnage stresses, enabling movement and establishing in new evolving ecosystems, is needed. However in conventional landscape approach both inter-disciplinary and trans-disciplinary are possible to adopt but, for effective implementation of sustainable multifunctional landscapes requires trans-disciplinary engagement. Through trans-disciplinarily the foreign entities are connected and the special relationship becomes more related. It is true interactive exchange among 'scientists, practitioners and professionals' engaged in land use decision making where future vision and objective are exchanged, co-developed and proposed.[45]

2.2 Green Infrastructure

2.2.1 Green Infrastructure Definition

Green Infrastructure (GI) is a relatively a modern term. Moreover it has dissimilar annotation to different user since it covers a wide range of application. As a consequence one might across different definitions for GI. C. Davies et al defined GI as "physical environment within and between our cities, towns and villages. It is a network of multi-functional open spaces, including formal parks, gardens, woodlands, green corridors, waterways, street trees and open countryside. It comprises all environmental resources, and thus a GI approach also contributes towards sustainable resource management". [46]

42 Natural England & tcpa (2008) *The Essential Role of Green Infrastructure: Eco-towns Green Infrastructure Worksheet,* http://www.tcpa.org.uk/data/files/etws_green_infrastructure.pdf. Accessed on July 2010.
43 Wikipedia, *Principles of Intelligent Urbanism*, http://en.wikipedia.org/wiki/Principles_of_Intelligent_Urbanism.
44 Wikipedia, *Principles of Intelligent Urbanism*, http://en.wikipedia.org/wiki/Principles_of_Intelligent_Urbanism.
45 Mander, Ü., Wiggering, H. & Helming, K. (2007) *Landscape Tomorrow: Multifunctional Land Use, Meeting Future Demands for Landscape Goods and Services*. P1, P37.
46 Davies, C., MacFarlane, R., McGloin, C. & Roe, M. (2008) *Green Infrastructure Planning Guide*, *Version 1.1*.

In the USA, the Conservation Fund and USDA Forest Services defined GI as "the Nation's natural life support system – a strategically planned and managed network of wilderness, trails, parks, greenways, conservation easements and working lands with conservation value that supports native species, maintains natural ecological processes, sustains clean air and water resources, and contributes to the health and quality of life for America's communities and people." [47]

GI is defined by Chris Blandford Associates as the "multi-functional network of 'green spaces' and inter-connecting green corridors in urban areas, the countryside in and around towns and rural settlements, and in the wider countryside. GI is a natural life support system providing benefits for people and wildlife." [48]

2.2.2 Green Infrastructure Terminology

The term of GI is contemporary term. That is why it is essential to cover the importance of emphasizing and shifting in basic terms. The difference from conventional terms came as a distinction from conservation practice and as an attempt to change popular perceptions about Green opens space. One can illustrate the terminology effect by: To emphasize the value or degree of importance to act as a counterpoint placed in 'Gray' infrastructure in planning. Also the term green space gives the conceptual meaning that is nice to have while "Infrastructure" implies the necessity to have. Moreover, the green space is treated as isolated complex but the GI is an interconnected system of natural areas.

Recently, the term "GI" has been used to refer to a variety of structural elements from green roofs to advanced eco-friendly storm water management facilities. So there is an interconnection between GI and grey infrastructure. C Davies et al suggested a restrict distinction between green-gray might not be practical, since "there is a grey-green continuum of thinking relating to concepts surrounding 'infrastructure', although 'green' can be used to denote the function or facility provided by an element, even if it is not strictly 'green' in land use terms".[46]

So it can be dealt with as colour chart in which in the middle green-gray like cycle ways, see Figure 2.1. Moreover the role of water is viewed by researchers in GI field as being of major importance and has directed them to discuss a prospective sub-class of blue-green or turquoise infrastructure. [49]

It can be concluded by saying the main idea behind terminology difference is giving a message of the importance of green dimension in sustaining life on the Planet and as an emphasis to shade light on conceptual dimension of the Green approach in general and particularly in planning process. Also wide usability of term and strong interconnection emphasizes the approach of integrity in planning and use.

[47] Benedict, M.A. & McMahon, E.T. (2002) *Green Infrastructure: Smart Conservation for the 21st Century.* Volume 20, Number3, Autumn 2002, http://www.sprawlwatch.org/green/ pp21.
[48] Chris Blandford Associates (2007) Green Infrastructure Strategy: A proposed vision for connecting people places and nature. 11104901R_ Executive Summary_Final_DW_11-07. Greater Norwich Development Partnership (GNDP): West Sussex, UK.
[49] Mell, I.C. (2008) *Green Infrastructure: concepts and planning*. Newcastle University: FORUM E-journal 8 (June 2008): http://research.ncl.ac.uk/forum/v8i1/green%20infrastructure.pdf.

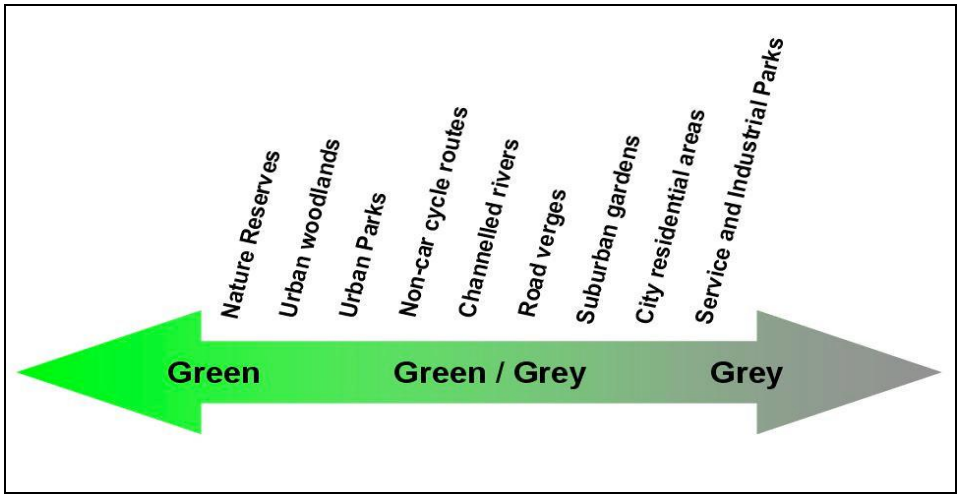


Figure 2.1: The Grey-Green continuum

Source: C Davies et al, Green Infrastructure Planning Guide.

2.2.3 Green Infrastructure Component

To push forward the aim of using GI in planning in a strategic level, it is so important to understand the GI component and its services, functions and benefit that can provide. The main structural constituent of GI illustrated by Mark A. Benedict, as "GI encompasses a wide variety of natural and restored native ecosystems and landscape features that make up a system of 'hubs' and 'links'." According to which Hubs "anchor GI networks and provide an origin or destination for wildlife and ecological processes moving to or through it." Hubs can be reserves, managed native landscapes, agricultural preservation districts, working lands, regional parks and preserves, community parks and natural areas, cultural/historic/recreational sites and trailheads. Links are the "connections that tie the system together and enable GI networks to work". Links can come in variety of function size and assets, like landscape linkages, conservation corridors, greenways, greenbelts, eco-belts, trail corridors and utilitarian corridors. Hubs and links vary in size, function and ownership [50]. Links may be "either an area or linear area of green space or they may be more towards the grey end of the green-grey infrastructure spectrum, such as multi-user routes or cycle paths through urban areas which link green spaces and networks" .[51]

As well as Chris Blandford Associates described the constituent with emphasis on the connectivity importance. Accordingly, GI encompasses "'natural green spaces' (colonized by plants and animals and dominated by natural processes) and man-made 'managed green spaces' (urban parks and designed historic landscapes), as well as their many connections (footpaths, cycle ways, green corridors and waterways)" [52]. While American Conservation Fund described the GI network component more in detail see Figure 2.2. Comprehending from above description GI encompasses natural, semi-natural greeneries and manmade green space within a connected green network to develop a complex system of green 'core, hub, corridors and links'.

[50] Benedict, M.A. & McMahon, E.T. (2002) *Green Infrastructure: Smart Conservation for the 21st Century.*
[51] Clabby, G. (2009) *Green Infrastructure: Critical Infrastructure for a Smart Economy.* http://www.comharsdc.ie/_files/Commentary%2040%20GReen%20infrastructure.pdf
[52] Chris Blandford Associates (2007) Green Infrastructure Strategy: A proposed vision for connecting people places and nature.

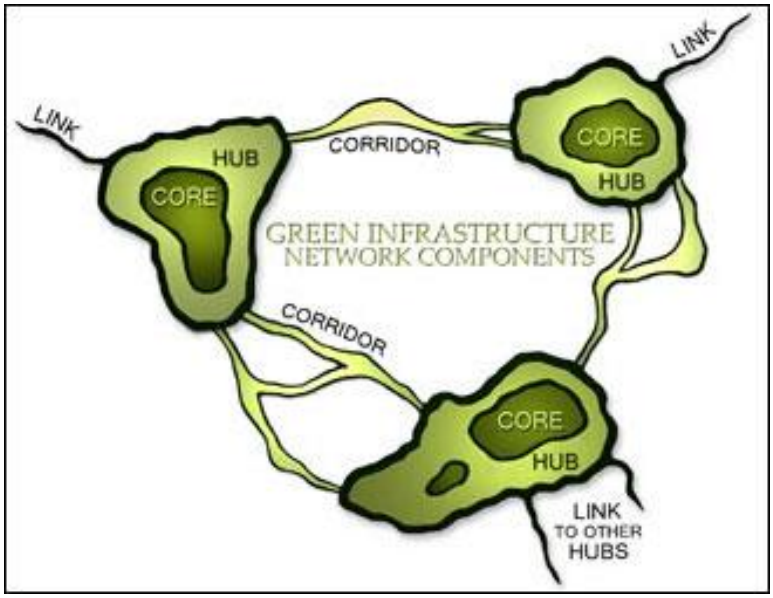


Figure 2.2: GI network components

Source: http://www.conservationfund.org/

In applied landscape ecology, the model for characterizing landscapes components is universally agreed on. The mosaic model applies three essential landscape components to describe landscape structure: "patches, corridors, and the matrix". A patch is a rather homogeneous nonlinear area that varies from its surroundings, while corridor is a linear zone of a specific land cover category, which is diverse in content and physical configuration. Each structure serves different functions. Patches offer compound functions containing "wildlife habitat, aquifer recharge areas, or sources and sinks for species or nutrients". Corridors functionality is also various such as "habitat for wildlife, pathways or conduits for the movement of plants, animals, nutrients, and wind, or as barriers to such movement". [53]

In addition to what mentioned above, the listed components illustrate a variety of landscape structures that is categorized under the GI umbrella and can be considered in strategic planning process as prerequisite, such as:

"**Designated Landscapes:** Includes National Parks, Areas of Outstanding Natural Beauty**,** Heritage Coasts**,** Sites of Special Scientific Interest**,** National Nature Reserves**,** and Scheduled monuments.

Transport corridors: Rail corridors**,** Motorways and trunk road verges**,** Rivers and canals**,** Footpaths, Bridleways, Cycle routes and Greenways**,** and Streetscape trees and planting.

Managed landscapes: Includes Agriculture and horticulture, Set aside and fallow land, Woodland, Reservoirs, Cemeteries and churchyards, and Brownfield and Greenfield development sites.

Recreational landscapes: Includes Amenity green space and private gardens, Allotments, Community gardens, Urban farms**,** Access land (as defined by CROW Act 2000)**,** Urban Parks**,** Country Parks**,** Playing fields and play areas**,** Lakes, and Ponds." [54]

[53] Ahern, J. (2007) *Green infrastructure for cities: The spatial dimension.* University of Massachusetts, http://www.stadtentwicklung.berlin.de/umwelt/landschaftsplanung/bff/en/bffberechnungshtml. Accessed on July 2010.

[54] ECOTEC (2006) *City Region Green Infrastructure Strategic Planning, Raising the Quality of the North's City Regions,* http://www.thenorthernway.co.uk/downloaddoc.asp?id=545.

2.2.4 Green Infrastructure Planning Approach

"During the nineteenth century, the leading idea in open space planning was to make patches of green, called parks. In the twentieth century, it was to make strips of green, called parkways or greenways". The conventional approach was a quantitative approach in which the emphasis was on the increase of green area percent. As a result this approach leads to isolated parks and green patch without connection. Then the landscape planers shift to qualitative approach in which the spatial planning integrated to provide greenways to connect the isolated green areas. Recently (last decades) another dimension is integrated which is multi-functional performance of different green typology. However in Planning this multi-functional benefit doesn't take in to account and sometimes simplified to single land use type. This is addressed and covered according to GIP approach.[55]

GI permits an emphasis on maximizing welfares in the formation of a linked and multi-functional green space network. Hence connectivity and multi-functionality are basic principles in GIP. Land-use planning is the main discipline that can integrate and account for environmental concerns effectively. "Planning utilizing GI differs from conventional open space planning because it looks at conservation values in context with land development, growth management and built infrastructure planning". Thus the GI methodology is to be considered as a long-term framework for sustainable development, preserving the natural and historic environment and improving their unique qualities. [56]

Moreover GIP epitomizes "the coming together of various interests. It is not seen just as a way of providing an improved green structure for the landscape, but also as a mechanism for more informed decision-making and more 'joined-up' thinking in relation to urban and regional environmental planning. [57]

2.2.5 Green Infrastructure Spatial Level

GIP is an umbrella approach for integrating the different planning policy namely "Tradition of Urban Parks, Urban Forestry, Landscape Ecology, Ecological Networks, Greenways and Green corridors", So GIP can be carried out at a variety of level starting from neighborhood or local to the regional and national scale, in response to informed and coordinated planning.

"GI must be planned strategically and delivered in an integrated way across the whole Sub-Region and at all spatial planning levels. The principles of GI should be integrated into Local Development Frameworks and the investment plans of those responsible for the planning and delivery of growth and environmental management within the Sub-Region". [58]

Since the aim of GIP is to put together the different strategy and different plan, to deal with it at city level will be a limited level since this level will not affect the regional and strategic planning decision. On the other hand to deal with it at regional level it wouldn't be to the required detail level of GIP concept of achieving multi functionality and need analysis. "So, the issue of scale in relation to GI is one of establishing at the regional scale what the strategic elements and links are in relation to the

[55] Amati, M. (2008) *Urban Green Belts in the Twenty-first Century*, http://www.ashgate.com/isbn/9780754649595.
[56] Benedict, M.A. & McMahon, E.T. (2002) *Green Infrastructure: Smart Conservation for the 21st Century.* pp12.17
[57] Community Forests Northwest (2010) *Green Infrastructure to Combat Climate Change: A Consultation Draft Action Plan for Cheshire, Cumbria, Greater Manchester, Lancashire, and Merseyside,* http://www.greeninfrastructurenw.co.uk/resources/GI_and_CC_Action_Plan_Consultation_Draft_02.09.10.pdf
[58] Jane Heaton Associates (2005) *Planning Sustainable Communities: A Green Infrastructure Guide for Milton Keynes & the South Midlands*, http://www.eera.gov.uk/Documents/About%20EERA/Policy/Environment/2005-07-04%20FINAL%20GI%20BROCHURE%20(2).pdf.

multifunctional demands placed upon them and then 'filling in the gaps' at a sub-regional and local level. Filling in the gaps requires that more detail is layered in at a sub-regional and again at a local scale." [59]

GI plan at regional scale or higher tier, is logical regarding the acquiescence with the rising demands of environmental regulation policy. This comprises the "Habitats, Birds and Water Framework Directives, which are concerned with nature conservation and water resources, and the Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA) Directives, all of which have major implications for planning". [60] Thus GI enables these legislative needs to be meet more straightforwardly and enables joined-up thinking of overlapping – requirements of different legislation. Also it will be a mean to rationalization of multi-tier strategies and plan.

Working at different spatial level may have a duality effect if not planed and integrated well. Since the special level of GIP is abstract, in, Green Infrastructure Planning Guide, C Davies et al, developed a flexible methodology to describe different planning scale level for Northeast region in UK, see Table C.1 (Appendix C).

2.2.6 Green Infrastructure - Key Principles

In order to deliver the ecosystem benefit of GI efficiently and comprehensibly, it is essential to tackle the main ideas during planning, implementing and managing process of GI. Such as:

- "The need to design holistically so that GI functions as a collective and connected whole;
- The need to plan comprehensively with the use of intelligence-led planning tools to address and deliver social, economic and environmental benefits;
- The need to plan and deliver strategically at the landscape scale, without the constraints of administrative boundaries;
- The need to secure public involvement and ownership of plans, including private landowners and community groups;
- The need to bring together skills, knowledge and resources of diverse professions, including strategic and local planning, economics, community forestry and landscape ecology; and
- The need for robust funding models to ensure that Green Infrastructure is delivered as a primary public investment with capital and sustainable revenue support." [61]

2.2.7 Green Infrastructure –Standard

Since GIP is up-to-date approach there is no fixed standard for it, but rather it is adaption of and modification of other standard. C Davies et al on the base of "Accessible Natural Green space Targets (ANGSt). Urban Nature, and Green Cities Declaration 2005 – Urban Environmental Accords" set GI standard called Accessible Natural Greenspace Standard Plus (ANGST+). English Nature ANGSt is used in a modified form. The improved ANGSt standard considers stakeholder participation, local decision making and connectivity, the latter is an essential constituent of infrastructure; green or grey.

- "No person should live more than 300 m from their nearest area of natural green space of at least 2 hectares in size;
- There is provision of at least 2 hectares of natural green space per 1,000 population;
- That there should be at least one accessible 20 ha site within 2 km from home
- That there should be one accessible 100 ha site within 5 km;" [61]

[59] Davies, C., MacFarlane, R., McGloin, C. & Roe, M. (2008) *Green Infrastructure Planning Guide.*

[60] Clabby, G. (2009) *Green Infrastructure: Critical Infrastructure for a Smart Economy.*

[61] TEP (2005) *Advancing the Delivery of Green Infrastructure: Targeting Issues in England's Northwest,* http://www.greeninfrastructurenw.co.uk/html/index.php?page=resources&NorthWestRegion=true.

- "That there should be one accessible 500 ha site within 10 km.
- That adjacent green spaces are interconnected; the priority and extent being determined by local decision making informed by stakeholder involvement." [62]

The Biotope/Green Area Factor program of Berlin-Germany, is the process of increasing and decentralizing urban GI (with important aggregated effect to enhance the urban ecology) implemented at the microscale (parcel or building). The green space targets had been regulated depending on land use: "residential 60%, mixed use 40% and commercial/city center at 30% – recognizing that the targets must differ in response to land use intensity". The strategy is triggered by a property auction or renovation projects. [63]
The eco-town planning regulation sets the target for soft GI portion as 40% of the entire land – comprising private gardens – and the same percentage of any single development site, must be reserved for GI. [64]
Time-saver standards for urban design, set total percent of Parks, Greens and Playground as 13.8%, 10.8% and 10.4% for Low cost neighborhood, Neighborhood unit for an industrial section and Apartment house unit correspondingly. [65]

2.2.8 Ecosystem Services of Green Infrastructure

Human beings are "fundamentally dependent on the flow of ecosystem services" [66]. Different green areas will have different ecological functions and thus offer different ecosystem services. These multiple ecosystem services range from food production and water provision, to aesthetic and recreational aspects. Natural, semi-natural and cultivated ecosystem and landscape "provide many goods and services to human society that are of great ecological, socio-cultural and economic value (Millennium Ecosystem Assessment, 2005)" [67].

In the last decades, a lot of research and study covered the multiple benefits that provide by ecosystem and GI. Despite all literature about ecosystem services but there is no clear definition. Millennium Assessment made an attempt to bring together different terminology of "functions", "goods" and "services". Regardless of controversy in terminology, four main groups of services are primarily classified by Millennium Assessment: provisioning, regulating, cultural and supporting services.

The time scale also shifted the functionality perspective of green dimension in general and landscape and urban forestry in particular, from the beginning of 20th century to the late 1970s the main interest were on productivity and recreational function of landscape while since 1970s and 1980s the society began to pay more attention to natural capital and non-productivity issue of the landscape and ecosystems, and aims to dissociate economic development from environmental degradation.[68]

Recently the GI approach can be seen as an attempt to boost the potential of all ecosystem services that can be provided by greeneries if they planned, managed in an integrated way. GI can therefore be seen as a key delivery mechanism for multi-functionality. Underpinning the multiple functions

[62] Davies, C., MacFarlane, R., McGloin, C. & Roe, M. (2008) *Green Infrastructure Planning Guide*, *Version 1.1*
[63] Ahern, J. (2007) *Green infrastructure for cities: The spatial dimension.*
[64] Natural England & tcpa (2008) *The Essential Role of Green Infrastructure: Eco-towns Green Infrastructure Worksheet*
[65] Watson, D., Plattus, A. & Shibley, R. (2003) *Time-Saver Standards for Urban Design: Urban Design and Climate*. pp, 382.
[66] Millennium Ecosystem Assessment (2005); Ecosystems and Human Well-Being, Synthesis. p. v.
[67] Millennium Ecosystem Assessment (2005) *Strengthening Capacity to Manage Ecosystems Sustainably for Human Wellbeing, Synthesis Report***.** pp 219.
[68] O'Farrell, P.J. & Anderson, P.M.L. (2010) Sustainable multifunctional landscapes: A review to implementation. pp 19.

that GI assets provide is the notion of ecosystem services. Below are the key services that GI can provide.

- **Provisioning function:** it supplies "physical services" in term of resources (food, fiber fuel) or space. It has been classified into two categories production and carrier function. The former category cover resource produced by natural ecosystem (harvesting wood in natural forest), while later category include resources that produced by human intervention (agricultural).
- **Regulation function:** it reflects the capacity of ecosystem to mitigate climate, air quality, hydrological and bio-chemical cycle, earth surface process and a diversity of biological process.
- **Habitat function:** comprise the ecosystem role in maintaining natural process cycle and biodiversity function. However the "relationship between biological diversity and ecosystem function are inherently complex and operate at many spatial and temporal scales" [69] This function have been subdivided to refugium and nursery function. The first is the role of ecosystem in providing habitat to threatened species, while the latter indicates that some ecosystem "provide a particularly suitable location for reproduction and thereby have a regulating impact of population elsewhere".
- **Cultural and amenity function:** non-material benefit for people. It covers the sensual, functional and visual benefit that people gain from landscape through recreation, cognitive development, relaxation and spiritual reflection. [70]

Table 2.1: Typology of ecosystem functions, goods and services

Source: Patrick J O'Farrell et al, 2010.

Ecosystem Function		**Short description**	**Biophysical Indicators (ecosystem properties providing the good and service)**	**Goods and Services**
Provisioning	production function	Resource from un-manipulated ecosystem	-Biomass (production and stock) – Biochemical properties -Etc	-Fresh water(*-Food(e.g. fish, bush meat)- Row material(wood, fodder, etc) -Etc
	carrier function	Use of space to (enhance) supply resources or other goods and services	Depending on the specific land use type, different requirements are placed on environmental conditions(e.g. soil stability and fertility, air and water quality, hydrology, topography, climate, geology, etc.	-Cultivation(e.g., agriculture, plantations, aquaculture) - Energy conversion(e.g. wind, solar) – Mining (ore, fossil, fuels, etc.) – Transportation (esp. on waterways) -etc
Regulation function		Direct benefit from ecosystem	Role of the ecosystems in biogeochemical cycles(e.g.	-Climate regulation – Maintenance of soil fertility –etc.

[69] Samson, F.B., & Knopf, F.L. (1996) *Ecosystem Management, Selected reading: Biodiversity and Ecosystem Function (Paul G. Risser).* pp 451.

[70] O'Farrell, P.J. & Anderson, P.M.L. (2010) Sustainable multifunctional landscapes: A review to implementation.

	processes	CO2/O2 balance, hydrological cycle)	
		Role of vegetation and biota in removal or breakdown of nutrients and toxic compounds	Waste treatment (e.g. water purification) – Maintenance of air quality
		Physical properties of land cover	-Water regulation (e.g. buffering runoff) – Erosion prevention – Storm protection and flood prevention
		Population control through tropic-dynamic relations	-Biological control (of pests and diseases); -Pollination
		Etc.	Etc.
Habitat function	Maintenance of biodiversity and evolutionary process	Presence of rare/ endemic species ; species diversity, etc.	Refugium of wildlife
		Reproduction habitat for majority of species	Nursery function (for commercial species)
Cultural and amenity function	Non-material benefits	Landscape (or ecosystem) properties with aesthetic, recreational, historic, spiritual, inspirational, scientific or educational value	-Enjoyment of scenery (e.g. scenic roads –Eco-tourism and recreation –Heritage value/ cultural landscape-Spiritual or religious sites –Cultural expressions (use of landscape as motive in books, films ,painting, folklore, advertising, etc) –Research and education.

*) Strictly speaking fresh water is not "produced" but constantly recycled. Because water is an important (essential) resource, the storage of water is seen as separate form water-purification which often underlies different process (e.g. cleaning of rainwater by vegetation or microbial activity in water) and often takes place in different compartments of the landscape.

2.2.9 Green Infrastructure (Function) Benefits

The controversial idea about differences between GI ecosystem services and function lead the author to deal with this topic distinguishably. Since GI functions "are the roles that assets can play if planned, designed and managed in a way that is sensitive to, and includes provision for, natural features and systems." [71] Therefore the function is the actual performance and consequent benefits of any GI typology with many potential ecosystem services.

At a general level five broad sets of interests in GI can be identified:

- **"Sustainable resource management** – particularly relating to the role of GI in the sustainable management of land and water resources, including production (e.g. energy and food crops), pollution control, climatic amelioration and increased porosity of land cover.
- **Biodiversity** – particularly relating to the importance of connectivity of habitats at a variety of landscape scales;

[71] Landscape Institute (2009); Green infrastructure: connected and multifunctional landscapes.

- **Recreation** – particularly relating to greenways and the use of non-car routes to address public health and quality of life issues;
- **Landscape** – examining resources such as green spaces and corridors from aesthetic, experiential and functional points of view;
- **Regional development and promotion** – particularly relating to sustainable communities issues relating to overall environmental quality and quality of life"[72].

Since GI is "A wide range of natural and manmade green and blue spaces that sustain natural ecological process and provide multiple social, economic and environmental benefits" [73], so the function can be summarized in the three pillars of the sustainability approach namely environmental, social and economical, benefits to individuals, businesses, communities and to the natural world. Moreover, GI provide a framework of future growth in sustainable way. The benefits of GI are mainly emphasized in built-up areas areas where vegetation index is limited and environmental risk and damage are more intensive. In order to plan properly, manage and maintain in a feasible way it is important to understand the functions and consequent benefits well. The functions and benefits are interrelated and go hand-by-hand together, see Table C.2 (Appendix C). Include summery of the key benefits of GI.

2.2.9.1 Climate Engineering Benefits

A. Urban Climate

- **Climate Change Effect**

Climate change is a fundamental challenge facing the world and humanity. Global warming with the frequency and magnitude of flood events, and desertification is increasing due to increasing rate of anthropogenic emission of GHG into the atmosphere. One of the main causes is human activity. Climate change effects are breadth and complex, also it differs in type and intensity according to geographical location,

Generally Phenomena like: "warmer and fewer cold days, warmer and more frequent hot days and nights, warmer spells/ heat waves, area affected by droughts increases, intense tropical cyclone activity increases and increased incidence of extreme high sea level" are predicted, see Table C.3 (Appendix C) in which IPCC illustrated the main weather impacts.

- **Urbanization Effect on Urban Climate**

Urban climate is changing due to capping of previous surface and converting to impervious surface, this in addition to all human activities that are affecting built environment and natural environment. City's land cover dramatically shifted, (vegetation cover reduced) due to human activity. This changes lead to 'cumulative' and 'systemic' urban issues, and will alter the ecological performance of the cities. "Cumulative issues can arise in any human settlement but may be exacerbated in towns and cities; an example of such an issue is building energy use. Systemic issues, on the other hand, arise because of the unique social, economic and environmental characteristics of urban settlements; an example is the urban heat island effect with consequent impacts on human health,

[72] Davies, C., MacFarlane, R., McGloin, C. & Roe, M. (2008) *Green Infrastructure Planning Guide*, *Version 1.1*.

[73] URS (2008) *Green Infrastructure. Northwest Regional Development Agency, Invest in England Northwest European Regional Development Fund.* http://www.erdfnw.co.uk/admin/uploads/attachment/Environmental_Sustainability_Guidance-GreenInfrastructure.pdf accessed on 3-7-2010

energy consumption and biodiversity" While the former should be dealt with at the strategic level the latter must be dealt with at a local level. [74]

Some major effects of urbanization have been identified and studied by researchers. The effect of Urbanization on increasing urban temperature which is known as 'Urban Heat Island', the amount of surface run-off and eventually causing flood risk and Carbon dioxide production with decreasing and disrupting biodiversity. [75.] All this effects are well connected to climate change cause and effects.

All together (climate change and urbanization effect on urban climate) are intensifying the rise of urban temperature 'Urban Heat Island' and increase of surface run-off in human dominated landscape.

B. Adaptation Strategy via Green Infrastructure

The adaptation measures implementation and design process ought to be adequately flexible to perform their designated aims under a difference upcoming climatic conditions.[76] As the source and impact of climate change and urbanization is vary also the mitigation and adaptation strategy are vary as well. In the course of this paper the author will focuses on the use of GI as adaptation strategy.

"GI provides a range of services that make a substantial contribution towards climate change adaptation and a limited but important contribution towards climate change mitigation. In addition to climate change mitigation and adaptation, GI also provides a range of other benefits making it a desirable way to combat climate change" [77.]

Urban greeneries "from street trees, to private gardens, to city parks provide vital ecosystem services which will become even more critical under climate change". In a research by Gill, S.E. et al, the GI moderating capacity of climate change impacts has been assessed in built-up areas that was associated to compactness degree. However, the model outputs indicate which typology of green are potentially with high benefit and in which settings.

Whitford, V. et al used 'Urban Ecological Index Module' in a comparison of four residential areas (in Liverpool, United Kingdom) by applying four ecological indicators (Temperature, hydrology, carbon storage and sequestration and biodiversity indicator). It has been concluded that the highest ecological performance which indicate better urban climate directly proportional with the percentage of urban green areas.

[74] Gill, S.E., Handley, J.F., Ennosb, A.R., Pauleit, S., Theuray, N. & Lindley, S.J. (2008) *Characterising the Urban Environment of UK Cities and Towns: A Template for Landscape Planning*. Landscape and Urban Planning 87. pp.210–222.

[75] Whitfort, V., Ennos, A.R. & Handley, J.F. (2001) *Landscape and urban planning: "City from and natural process" – indicators for the ecological performance of urban areas and their application to Mersevside.* University of Manchester, UK, www.elsevier.come/locate/landurbplan,

[76] Smith, J.B. (1996). Development of adaptation measures for water resources. International Journal of Water Resources Development, pp.151-163.

[77] Community Forests Northwest (2010) *Green Infrastructure to Combat Climate Change: A Consultation Draft Action Plan for Cheshire, Cumbria, Greater Manchester, Lancashire, and Merseyside.*

- **Managing Hydrology**

- Surface Run-off

Climate change leads to increase of intensity and frequency of winter precipitation by different range depending on geographical location. Together with urbanization that is marking by converting permeable surface to impermeable (building, roads other hard surface) the amount of surface run-off will increase, due to several factors. This may lead to flood risk, since the existing urban structure will not cope with this incremental trend. "In order to adapt to the increased winter precipitation expected with climate change, green space provision will need to be considered alongside increased storage".[78]

Obstructing the runoff before it reaches the soil surface is decreased due to reduced vegetation cover. Likewise, evapotranspiration process is decreased during and after the storm since there is less vegetation cover. Also, "the infiltration process will be reduced due to change in proportion of permeable area", see Figure 2.3.[79]

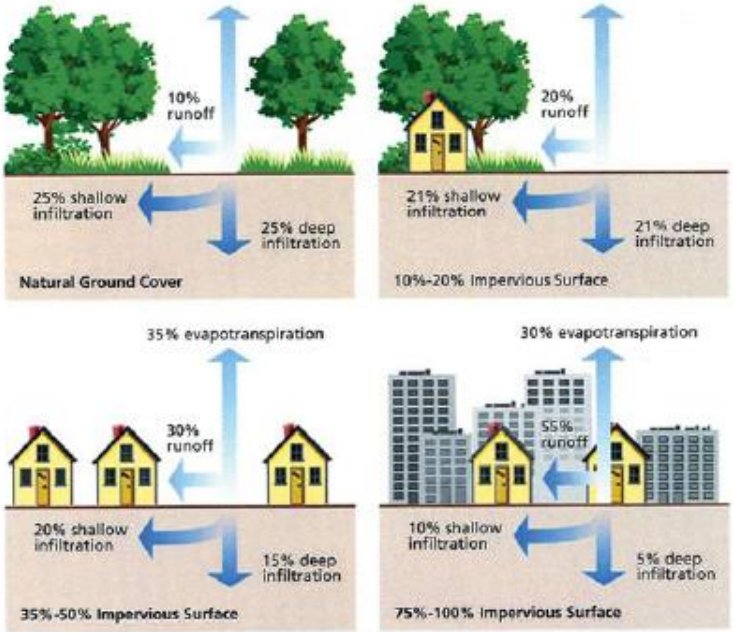


Figure 2.3: Effects of natural and impervious surfaces on the hydrology cycle

Source:http://www.greeninfrastructurenw.co.uk/resources/GI_&_Hydrology_Report_May_2009.pdf

In a research by Gill, S.E. et al about Greater Manchester, quantify the potential of the GI in reducing surface run-off by using 'Surface Run-off Model' by Whitford, V. Increasing green cover by 10 % in "the residential UMTs reduces runoff from these areas from a 28 mm precipitation event, expected

[78] http://ciceet.unh.edu/living_coasts/projects/green_area_ratio.html
[79] Whitfort, V., Ennos, A.R. & Handley, J.F. (2001) *Landscape and urban planning: "City from and natural process" – indicators for the ecological performance of urban areas and their application to Mersevside.*

by the 2080s High, by 4.9 %; increasing tree cover by the same amount reduces the runoff by 5.7%".[80]

Whitford, V. et al used 'Surface Run-off Model' to measure decrees in surface run-off quantity in relation to vegetation cover portion. The storm run-off coefficient has been chosen as performance indicator to show the effect of urbanization on hydrology. The following equations have been used:

$$P_e = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad S = \frac{2540}{CN} - 25.4$$

Where: P: precipitation

S: maximum potential retention of the catchment (grater S smaller run-off)

CN: curve No. of particular type of watershed.

To illustrate the model land cover map, precipitation data, curve No. approach and hydrological soil type is necessary as input data.

- Water Resource Management

The effect of climate change, particularly global warming is causing reduction in precipitation rate, water scarcity and desertification in different geographical area.

In this concern, GI is an effective way to manage the water source sustainably especially at the watershed area, since it enhance groundwater recharge. "The natural infiltration capabilities of GI technologies can improve the rate at which groundwater aquifers are 'recharged' or replenished. This is significant because groundwater provides about 40% of the water needed to maintain normal base flow rates in our rivers and streams. Enhanced groundwater recharge can also boost the supply of drinking water for private and public uses" [81]. This can be regarded as one of considerable mitigation measure for water scarcity problem.

On the other hand in to this extreme (drought) there is a flood risk in wet weather. GI is a means for managing riverine flooding, through providing water storage, retention areas and enhancing infiltration capacity.

"GI reduces storm water runoff volumes and reduces peak flows by utilizing the natural retention and absorption capabilities of vegetation and soils. By increasing the amount of pervious ground cover, GI techniques increase storm water infiltration rates, thereby reducing the volume of runoff entering the lakes, rivers, and streams." [82] This function is quite important since it decrease runoff volume to the flowing body as surface water in the wet season and enhancing groundwater recharge that can be used as a recharge source of rivers or as a direct source of water supply in dry season. GI especially trees, is of considerable importance in urban areas and urban watersheds for the various benefits they provide. The USDA Forest Service in a manual on Urban Watershed Forestry gives information on increasing forest cover in a watershed through protection, enhancement, and reforestation. Regional Ecosystem Studies conducted by American Forests to give lost forest an

[80] Gill, S.E.; Handley, J.F.; Ennos, A.R. & Pauleit, S. (2007) *Climate change and cities Adapting Cities for Climate Change: The Role of the Green Infrastructure*. Built Environment, Vol 33, NO 1. http://www.fs.fed.us/ccrc/topics/urban-forests/docs/Gill_Adapting_Cities.pdf

[81] U.S. Environmental Protection Agency (2008) *Managing Wet Weather with Green Infrastructure Action Strategy 2008,* http://www.epa.gov/npdes/pubs/gi_action_strategy.pdf,

[82] http://www.epa.gov/npdes/pubs/gi_action_strategy.pdf

economic value. For the Baltimore-Washington area it was estimated that tree cover declined from 51% to 37% between 1973 and 1997. This decrease in forest cover was estimated to have resulted in an increase in storm water runoff by 19%. ND eventually decreasing groundwater recharge and increasing cost of storm water facility in which estimated by $1.08 billion. [83]

Moreover GI is an effective way for managing the quality of water source through storm water pollutant reductions. "GI techniques infiltrate runoff close to its source and help prevent pollutants from being transported to nearby surface waters. Once runoff is infiltrated into soils, plants and microbes can naturally filter and break down many common pollutants found in storm water". [84]

- **Managing High Temperatures**

Global warming is the most challenging and serious issue that affecting biotic and abiotic in any ecosystem. It is the rise in average global temperature as a result of growing levels of GHG in the atmosphere. "Climate change results in a total increase of temperatures of 0.74 °C between 1906 and 2005. However, in the past 50 years temperatures increased by 0.13 °C per decade leading to the assumption that global warming is getting faster as time goes by. Temperatures have been estimated to rise by up to 3 °C by year 2050". [85]

As urban morphology type are changing towered increasing hard surface (surfaces that absorb and retain heat). The cooling effect or degree of energy emitted by buildup material is dramatically different from the natural or vegetated cover. "The displacement of trees and vegetation minimizes their natural cooling effects. Additionally, tall buildings and narrow streets trap and concentrate waste heat from vehicles, factories, and air conditioners". As a result "in big cities it is common to observe, at the late hours of the nights, air temperatures that are 3–5 °C (5.4–9°F) higher than the surrounding areas, and in extreme cases, higher by up to 8–10 °C (14.4–18°F)". The difference in temperature dependant on character and size of city, population density, geographical and meteorological condition land cover percent, built-up urban area, building density and building topology. Another effective feature is the "ratio of building heights to the distances between them can have strong effect on the magnitude of the Urban Heat Island"[86]. The trees, green roofs and other typology of GI are proving shade, reduce the amount of heat absorbing materials and emit water vapor all of which cool hot air, eventually reducing the effect of Urban Heat Island. [87]

The urban greeneries, indirectly but effectively are reducing urban temperature by increasing energy efficiency. This lead to decreasing the energy demand for mechanical heating and cooling thereby decreasing emissions from power plants. This will eventually decrease the GHG emission and effect of climate change. As well as it decrees the intensification of the urban heat island through anthropogenic heat. [88]

In a research by Gill, S.E. et al, quantify the potential of the GI in reducing temperature by using 'Energy Exchange Model' by Whitford, V. Depending on two emissions scenarios, by 2080s there are upsurges in maximum surface temperature of between 2°C to 4.3°C in town centers. Adding 10% green cover to the city core and high-density residential UMTs, preserves maximum surface temperatures at or under the baseline temperatures, but not including the 2080s High emissions

[83] Bartens, J. & Mersy Forest Team (2009) *Green Infrastructure and Hydrology. Mersy Forest,* http://www.greeninfrastructurenw.co.uk/resources/GI_&_Hydrology_Report_May_2009.pdf.

[84] http://www.epa.gov/npdes/pubs/gi_action_strategy.pdf

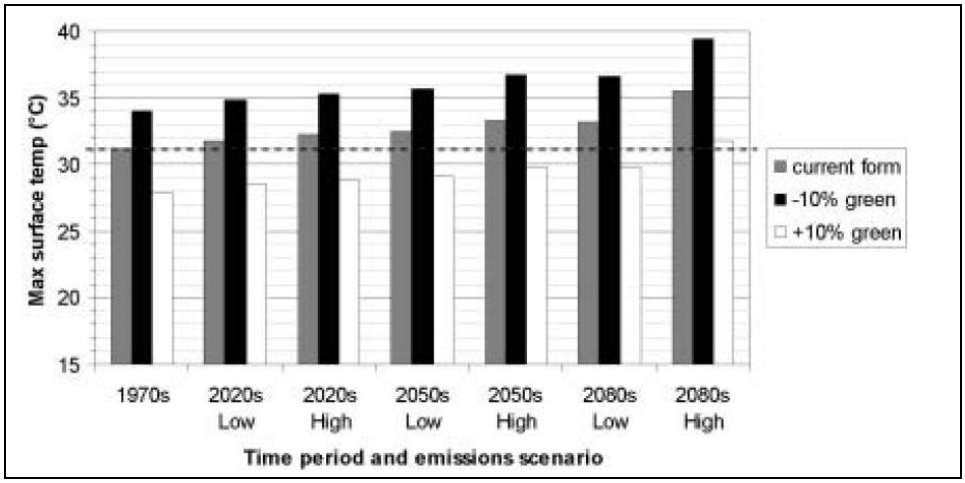
[85] Bartens, J. & Mersy Forest Team (2009) *Green Infrastructure and Hydrology. Mersy Forest,*

[86] Watson, D., Plattus, A. & Shibley, R. (2003) *Time-Saver Standards for Urban Design: Urban Design and Climate*. pp, 382.

[87] U.S. Environmental Protection Agency (EPA), *Managing Wet Weather with Green Infrastructure*, http://cfpub.epa.gov/npdes/greeninfrastructure/technology.cfm

[88] Benedict, M.A. & McMahon, E.T. (2002) *Green Infrastructure: Smart Conservation for the 21st Century.*

scenario. On the other hand, if 10% green cover is took away maximum surface temperatures by the 2080s High emissions scenario are 7°C and 8.2°C warmer in compact morphologic setting, compared to base temperature scenario at the 1961–1990, see Figure 2.4. It is worth to mention that the degree of impact was less in the area with higher percent of vegetation cover. [89] Another study in Munich estimated an "increase of tree canopy cover by 10% reduced surface temperature on average by 1.4 °C". [90]



*Dashed line shows the temperature for the 1961–1990 current form case.

Figure 2.4: Maximum surface temperature for the 98th percentile summer day in town centre, with current form and when 10 per cent green cover is added or removed.

Source: Gill, S.E. et al.

Whitford, V. et al used 'Energy Exchange Model' to illustrate cooling effect or 'climate indicator' in relation to land covers proportion. "The model proceeds by expressing the surface energy balance of an area in terms of its surface temperature, T0, and by linearising all equations. It proceeds from a simple instantaneous energy balance equation". To sum up the input of "the metrological and physical parameters of the model; and the relative amount of green space and built environment" is needed.

R=H+LE+G+J

Where: R: net radiation flux to the earth surface,

H: sensible heat flux due to convection,

LE: Latent heat,

J: heat storage capacity.[91]

[89] Gill, S.E.; Handley, J.F.; Ennos, A.R. & Pauleit, S. (2007) *Climate change and cities Adapting Cities for Climate Change: The Role of the Green Infrastructure*. pp (115-133).
[90] Konijnendijk, C.C., Nilsson, K., Randrup, T B. & Schipperijn, J. (2005) *Urban Forest and Trees*. pp94.
[91] Whitfort, V., Ennos, A.R. & Handley, J.F. (2001) *Landscape and urban planning: "City from and natural process" – indicators for the ecological performance of urban areas and their application to Mersevside.*

- **Carbon Storage and Sequestration**

The rise of GHG emission in particular Carbon Dioxide due to fuel combustion for perusing activities, is in incremental trend in developing countries. This effect can be decreased by many mitigation policies. In this context the role of GI types in particular urban forest becoming recognizable. “The plants and soils that are part of the GI approach serve as sources of carbon sequestration, where carbon dioxide is captured and removed from the atmosphere via photosynthesis and other natural processes”. [92] Moreover, trees and vegetation refine air quality by filtering various airborne pollutants that contribute to the GHG effect.

On the base of energy policy, that includes the reduction of GHG through GI. GI contributes directly to air quality amelioration, and indirectly to energy saving due to decrease in demand for mechanical cooling and heating. Indirectly GI also contribute in reducing GHG emission.GI can provide opportunities for sustainable travel through the provision of high-quality, off-road walking and links. Transportation planning and enhancing more environmental friendly means like public transport, cycling and walking by providing short commute distance. “Also GI can provide “renewable energy crops” that substitute fuel and will reduce GHG emission”[93]. In this concern UK Climate Change Programme (2006) and Energy White Paper "Our energy future – creating a low carbon economy (2003), under the driver of climate change, are adopted two key policy. One of the main key policies is Green space production and renewable energy crops (biomass energy production) is a contribution to mitigate climate change –GHG emissions target to 12.5% below 1990 levels. [94]

However the “over all direct urban sequestration by urban trees accounts for 1% of carbon emission for urban areas”17 but stile the role of urban trees are vital due to indirect effect. The sequestration function is directly related to the size and type of green or in other words the capacity of up taking process. In a study, it has been assessed that the urban forest with around 6 million trees can sequester 23800 t of CO_2/ year in Sacramento County-California. Also due to indirect energy saving for mechanical conditioning 75600 t of CO_2 per year have been sequesters. [95] Forests generally have significantly higher above-ground carbon reservoirs than other vegetation types, making them especially appropriate for carbon storage and sequestration. In the North West of England, soils and vegetation store 2.5 MtC, with a mean density of 178 t C/ha. [96]

The approach of ‘Carbon Fixation’ quantifies the rate of carbon sequestration by using the following formal from Whitford, V. et al. The land cover map, tree cover and CO_2 and pollutant amount have been used as input data. With up to 0.13 t H-1 yr-1, well treed area sequestrated more than double amount of carbon than areas with poor vegetation.

Carbon storage (tonnes ha^{-1}) = 1.063* % tree cover

Carbon sequestration (tonnes ha^{-1} per year) = $8.275*10^{-3}$* % tree cover

- **Air Quality**

[92]http://cfpub.epa.gov/npdes/home.cfm?program_id=298

[93] http://www.epa.gov/npdes/pubs/gi_action_strategy.pdf

[94] ECOTEC (2006) *City Region Green Infrastructure Strategic Planning, Raising the Quality of the North's City Regions,*

[95] Konijnendijk, C.C., Nilsson, K., Randrup, T B. & Schipperijn, J. (2005) *Urban Forest and Trees*. pp98.

[96] Community Forests Northwest (2010) *Green Infrastructure to Combat Climate Change: A Consultation Draft Action Plan for Cheshire, Cumbria, Greater Manchester, Lancashire, and Merseyside,*

Air quality improvement becomes imperative policy in developing countries. “Air pollution is currently estimated to reduce the life expectancy in the UK by an average of 7-8 months with estimated health costs of up to £20 billion” at yearly base. One might come across the threshold limit for urban air quality by European Union. Different members had already achieved the goal and countries like Britain particularly in London city still in planning and putting strategy to be within permissible range. Air pollutants in both developing and developed country (with different range) are in incremental trend for some kind of pollutants. “Mainly car induced pollutants such as Nitrogen oxides; ozone and volatile organic compounds are of major concern in this regard Climate change is likely to add further to this problem because rising air temperatures and higher level of radiation can lead to higher concentration of Ozone in the air” [97]. The seriousness of this air quality management lay in its direct relation to human health, for instance air born pollutant can cause respiratory illness, ultraviolet radiation that may led to skin cancer in hot regions.

Different mitigation policy and strategies identified and applied in this concern, Most of them dealing with preventing or reducing emissions from the source. Since the source of pollutants is diffuse so other measures like ‘enhancing air circulation’ and ‘removing pollutants from the air’ are taking serious intention. In this regard the role of GI in improving air quality directly and indirectly of major concern.

Different GI type, particularly trees and woodlands, can absorb atmospheric pollutants through leaf uptake and contact removal. This can be adopted at large scale and local scale as well, so “If widely planted throughout a community, trees and plants can even cool the air and slow the temperature-dependent reaction that forms ground-level ozone pollution (smog)”. [98] GI particularly trees provide shelter from ultraviolet radiation and more importantly dust capturing function. A research in West Midland region of England projected that 25% of airborne pollutants can be reduced by planting the available dedicated land with 30000 trees also could reduce excess deaths due to particles in the air by up to 140/year [99]. Also another study in Nottingham was estimated the woodland to reduce sulfur dioxide and nitrogen oxide in the air by 4-5%. [100] Regional Ecosystem Studies conducted by American Forests to give lost forest an economic value. For the Baltimore-Washington area it was estimated that tree cover declined from 51% to 37% between 1973 and 1997. The lost tree cover estimated that it would have removed approximately 9.3 million pounds of pollutants per year from the atmosphere which would equal a value of $24 million per year. [101]

This filtration capacity depends on the thickness of green layers, “Wind tunnel studies have indicated that, in order to obtain equally advantageous effects on the emissions situation of particles and gases, a broad planting (>10 m wide) is necessary, which creates intermediary space for wind to pass through. A mixed planting of leafy and coniferous trees is recommended”, see Figure 2.5. Also another important factor is the tree type since a research shows that planting larch, pine and ash can help remove tiny polluting particles from the air of towns and cities. But other trees, like willow, oak and poplar, could exacerbate pollution. [102]

[97] Konijnendijk, C.C., Nilsson, K., Randrup, T B. & Schipperijn, J. (2005) *Urban Forest and Trees*. pp93.
[98] http://cfpub.epa.gov/npdes/home.cfm?program_id=298
[99] http://framework.rcuk.ac.uk/Hsoc/hcase.htm
[100] Konijnendijk, C.C., Nilsson, K., Randrup, T B. & Schipperijn, J. (2005) *Urban Forest and Trees*. pp93.
[101] Bartens, J. & Mersy Forest Team (2009) *Green Infrastructure and Hydrology. Mersy Forest.*
[102] http://framework.rcuk.ac.uk/Hsoc/hcase.htm

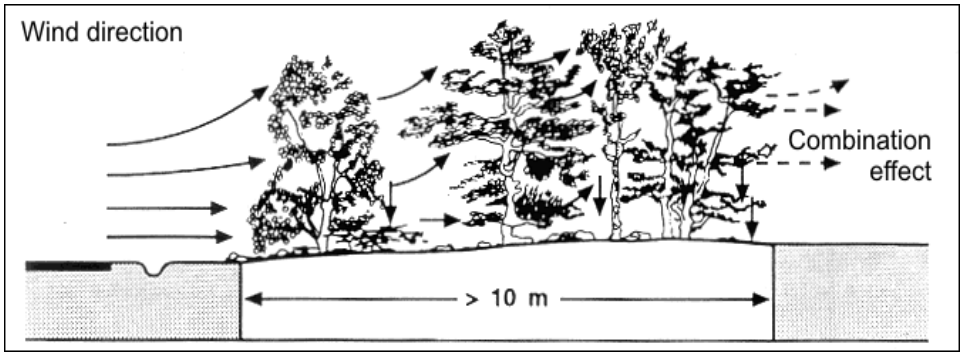


Figure 2.5: Planting of leafy and evergreen trees

Source: Ministry of Economy Baden-Württemberg, 2008.

A decrease of about 60% in emissions is usually possible, with efficient dust filtering capacity in summer and winter. No intensification of gaseous discharges in winter because of the mixed planting of evergreen and leafy trees. GI offers prospects for sustainable travel through the provision of high-quality, off-road walking and cycling links. This will directly contribute in reducing air pollutant emission in to the air, this regardless of emission reduction through energy saving effect.

2.2.9.2 Biodiversity

Biodiversity protection is one of the major topics for environmentalists now a day. There is widespread agreement that biological diversity is valuable and that it is rapidly being lost. Consequently the conservation of biodiversity has emerged as a major international issue. Approximately "99% of all species that have existed on earth are now extinct". Therefore, it is not feasible to reduce all the anthropogenic species extinctions. That is why the serious action to reverse extinction is based on the rate and scale of extinction. This can be identified by the "hierarchical approach" to protecting biological diversity, which is a specific application of general system theory. To identify endangered species and their ecosystem in human dominated landscape, special research and investigation should be making throughout the area of interest. The bigger challenge is the policy to reverse biodiversity loss: several approach like "endangered species", "nature conservation" and "multiple-use landscape" can be integrated to adopt as an action plan depending on site specific spatio-temporal characteristic. One of the "Sciences top 20 greatest hits" which is like a base for general science states " An expanded approach to biodiversity should include genetic and landscape diversity, not just species diversity" The biodiversity protecting policy should be at the landscape scale since the assortment of species depend on "size, variety, and dynamics of patches".[103] The ecological network concept implemented as an ideal spatial strategy at wide scales counting continents, nations and regions. However, it "has aimed primarily at maintaining biodiversity and has been rarely applied in urban contexts. This trend is changing with a focus on urban environments through the GI movement". [104]

One of the basic principal of sustainable design and planning is preserving biological diversity and environmental integrity. That is why a counter strategy (to conservation policy) at the same degree of importance is connectivity and integrity through green corridors or links to make them more viable. GI reverse habitat fragmentation and increase biodiversity to restore functioning ecosystems

[103] Samson, F.B., & Knopf, F.L. (1996) *Ecosystem Management, Selected reading: Biodiversity and Ecosystem Function (Paul G. Risser).* pp424, 331, 281, 282.
[104] Ahern, J. (2007) *Green infrastructure for cities: The spatial dimension.*

that underpin a rich wildlife resource. Moreover, "GI should be characterized by native species of flora and fauna, and particularly by habitats and species that are characteristic of the area". 105

GI can link "fragmented habitats and landscape features to make them more viable restore degraded sites and habitats, create new wildlife havens, and provide new spaces for recreation to reduce human impact on sensitive sites. GI networks can support the dispersal and migration of individual species and whole habitats, either as part of a regular movement pattern or through migrations in response to climate change".[106]

The protection nearby urban areas is also of great importance that is why "carefully planned green 'buffers', along with other mitigation measures, will often be required to physically and functionally distance new development from sensitive sites, protecting them not only from disturbance but also from physical changes produced by changes to water quality or hydrological patterns". [107]

2.2.9.3 Landscape Heritage and Historic Environment Conservation

This category is a combination of natural and manmade legacy. It consists of land, which includes landscapes of "historic, recreational, nature conservation", high visual qualities of the landscape or valuable habitat at high spatial tiers (metropolitan or national scale). So the strategy for reservation enhancement and restoration can be achieved with GI wide scope.

The conservation and protection policy of areas designated for their special landscape and/or biodiversity importance "National Parks, Areas of Outstanding Natural Beauty, Country Parks, Special Areas of Conservation, Special Protection Areas, Sites of Special Scientific Interests, Ancient Semi-Natural Woodland etc." are more cost effective and feasible than restoration strategy. Moreover, it will improve the productivity of tourism, creative and leisure industries, which will enhance economic growth.

"GI contribute to the protection and enhancement of the historic dimension of the present landscape, including particular historic assets Historic environment management plans should be produced for historic assets identified within GI networks, including options for conservation, enhancement and recreational and leisure use". Moreover, these sites should be avoided in the all kind of development as well as ensuring their accessibility through GI network and links.

"The Historic Environment Assessment uses techniques of Historic Landscape Characterization (HLC) with technical consideration of historic buildings and archaeological sites to consider the implications of future expansion and /or reservation". [108]

2.3 Introduction to Basic Green Infrastructure Typology[109]

GI includes a wide range of typology, which differ to respective spatial level and hierarchical scale of urban areas. Mainly site scale, metropolitan scale and regional scale are classified. Accordingly and depending on the scope of the study certain typology is highlighted under this section.

[105] Ahern, J. (2007) *Green infrastructure for cities: The spatial dimension.*
[106] Natural England & tcpa (2008) *The Essential Role of Green Infrastructure: Eco-towns Green Infrastructure Worksheet*
[107] Natural England & tcpa (2008) *The Essential Role of Green Infrastructure: Eco-towns Green Infrastructure Worksheet*
[108] Natural England & tcpa (2008) *The Essential Role of Green Infrastructure: Eco-towns Green Infrastructure Worksheet*
[109] Green Infrastructure Wiki, *Green Infrastructure Assets*, http://www.greeninfrastructurewiki.com/

2.3.1 Green Belt

2.3.1.1 Green Belt Concept

Emerge of green belt return back to 20th century, which was to prevent urban sprawl and encapsulation of residential and industrial growth. “In 1881 Cologne city two green rings with 4166 ha, were surrounded the city later developed to ring in 1923.” Nevertheless the first example is belonging to earlier time 1580, When Queen Elisabeth I designated a three-mile (ca. 4 km) perimeter greenbelt around London.[110]

In UK pre-WWII “planners invoked the green belt as a way of achieving the normative goals associated with preserving the landscape”. The green belt had conceptual association with the Garden Cities concept. Ideas of high modernism in planning and attempt to direct development of cities to sustainable patterns post-WWII, made the modernist planer to question green belt strategy as a valuable tool for handling urban development? Between these two poles, UK’s green belt debate about usefulness concept of green belt is under research.

Furthermore, a number of well-known alternatives to a green belt exist allowing planners to opt, for example for a ‘green wedge, a greenway or a green-web’, nevertheless green belt was the only policies that adopted by planners in different countries. Despite these debates, 14 cities in UK is surrounded by green belts, “where they have remained a dominant plank of national planning policy” for over 15 years.[111]

2.3.1.2 The Challenges and Strength of Green Belt Concept[112]

City’s limit specification: The responsibility of planner to determinant city’s boundary for a specific time interval is challenging. “A green belt was meant to be permanent, but on the other hand planners were expected to draw it on a development plan that would guide development over a 20 year period in London”.

The coalition of the un-willing: The clash between landowner’s interest and green belt planning implementation. In some country like Tokyo this affected landowner’s interest dramatically.

Deregulation and green belts: The changes and deregulation in planning system will affect the solidarity of implementation and reservation of green belt. The main organization which supports the green belt can be removed or altered. Also the regional planning can held a duality effect on green belt which can be supportive or destructive.

Re-forming greenery: a variety of different green space policies that can be adopted by planer and promotion to re-evaluation of the functions of urban green space is achievable in case of green belt. Like in Ottawa green belt evolved from an urban containment measure to an open space and ecological feature of a regional plan.

Public Support: a survey recorded that that although four out of five people agree that the green belts should be protected at all costs; people gave priority to preserving the green belt and providing green space for people to recreation.

Patching together a flexible green belt: A green belt is not rigid when used, rather, it is in most cases, patched together in a series of a broad range of activists. So it include a variety of activates and can be flexibly mannered according to spatio-temporal scale and bio-physical characteristic. London, Vienna and Berlin’s green belt are presently entails of a patchwork of diverse spaces.

[110] Konijnendijk, C.C., Nilsson, K., Randrup, T B. & Schipperijn, J. (2005) *Urban Forest and Trees*. pp29.
[111] Amati, M. (2008) *Urban Green Belts in the Twenty-first Century*,
[112] Amati, M. (2008) *Urban Green Belts in the Twenty-first Century*,

Common concept of green belt and modern planning: The rigorous separation of city and country in the green belt reflected the ecologist aversion towards hybrid landscapes but also coincided with the modernist preference for order. The complete exclusion of development forced by the green belt fixed by master plans and comprehensive planning adopted by modernist planners. The main function of green belt is to preserve the settlements size, as the base of planning dishpan is linked the size of cities to its inhabitants' wellbeing. [113]

2.3.1.3 Green Belt Function

The implementation of green belts in metropolitan areas can be considered as an international model to regulate urban development. Green belts surrounded big cities to stop sprawling effct, and to detach 'satellite towns' from the city core, preserving areas for recreation, cultivation and forestry. Green belts have provided locations for more practical usages as "salvage yards, incinerators and quarries". [113] With the urge of GIP the conceptual understanding of green belt as a model to control urban growth is shifting to the importance of ecosystem services that could provide. The following list of benefits of designing green belt.

Securing the Local Air Exchange: To insure a healthy urban microclimate, site plans – mainly in areas significant for the city' ventilation– there should be complete regulations for land use and building alignment and building high.

Resource management: free land suitable for cultivation due to location, soil quality and extent must be kept free of growth and should be designated as agricultural use.

Cold Air Production: It includes deciding about the suitable green typology and the required size, according to the function that will perform.

Fresh Air Supply: This by enhancing natural fresh or cool air corridors through getting benefit from difference in topography, because chiller air steadily moves in the direction of terrain slop to lower topographical zones.

Arrangement of Urban Bodies: Green belt prevents urban sprawl and gives identified urban form. The form and extent of hillside expansion are decisive for the formation of urban climate, in cities located in basin topographic setting. The development should be restricted in the hillside area by regulation, otherwise in case of development, low density strategy should be implemented. This to insure assessable low built-up portion, preserving large impervious surfaces and wide distances reserved between the individual buildings. Linear development alongside the hillside forms a extensive hindrance for down-slope winds.

Climate-regulating function: "Serve as lungs for cities and towns and as a sink for pollutants, check the flow of dust and bring down noise pollution level". [114] It reduces the impact of urban heat island with the high cooling effect that it provides. Moreover it reduce the amount of surface runoff.

Buffering Function: It Separate residential areas from emitting industrial and commercial areas as well as heavily-trafficked roads. It also lessens the effect of urbanized area on the surrounding agricultural landscape.

Biodiversity Function: It is Habitat for wildlife.

Recreation Function: enhance tourism, recreation and provide amenity for residents.

[113] Amati, M. (2008) *Urban Green Belts in the Twenty-first Century*,
[114] Urban Green Belt, http://edugreen.teri.res.in/explore/forestry/urban.htm,

The ecosystem services provided by a green belt is dependent on the distribution of land use, but never the less the climate regulation function is there. For instance, Breiling and Ruland inspect the green belt around Vienna. London's Green belt includes "aristocratic estates, farms, airfields, commons and golf courses wetlands, woodland and meadows". Those landscape elements can also be detected in the Vienna's green belt. Moreover, it includes "organic and small-scale to industrial-scale agriculture, areas for leisure, landscape preservation, tourism and ecology, which all enjoy different levels of protection". [115]

2.3.2 Urban Green Typology

2.3.2.1 Green Roof

"Green roofs (roofs with a vegetated surface and substrate) provide ecosystem services in urban areas, including improved storm-water management, better regulation of building temperatures, reduced urban heat-island effects, and increased urban wildlife habitat." Green roof mainly are of two categories. Intensive green roofs have the features of traditional ground-level gardens. Extensive green roofs are a modern alteration of the roof-garden concept. Since the latter category have shallower substrates layer so the ecosystem function of is limited to storm-water management, thermal insulation and fireproofing enhancement capacity. Intensive green roofs have the same function of extensive green roof in addition to aesthetic and increasing living space of buildings.

Since 1970s of last century due to environmental concern in Germany green roof technology rapidly progressed. Programs for promoting green roof technology and improving environmental standard to improve built environment is introduced. Recently, the erection of green roofs are the prerequisite by building law in several urban core zones "Green-roof coverage in Germany alone now increases by approximately 13.5 million m^2 per year. Haemmerle (2002) calculates that approximately 14% of all new flat roofs in Germany will be green roofs." [116]

Design features such as green roofs can enhance biodiversity, absorb rainfall, improve the performance of the building, reduce the urban heat island effect and improve the appearance of a development. [117] So green roof provide a variety of ecosystem function, see Table C.4 (Appendix C).

However green roof can be considered as a good option for densely populated areas but the harsh conditions of roof are challenging for plant survival and growth. Although always native plant is recommended since they are the best in coping with local climatic condition but it needs research and experiment in the case of green roof particularly extensive green roof. Since the climatic condition and availability of water is not the only factor that dictate the type of vegetation but also the depth of substrates is an essential element in the equation.

2.3.2.2 Green Wall

Also called **living walls, biowalls**, or **vertical gardens**, horizontal elements are not the only structural elements of building envelopes, which can be developed as green—gardens that are appearing on facades. Green wall can be a conventional fence of residential plot to a modern type with extensive cost and technology. For the latter two recent examples are a pleasingly unruly, vertical garden

[115] Amati, M. (2008) *Urban Green Belts in the Twenty-first Century*,
[116] Oberndorfer, E., Lundholm, J., Bass, B., Coffman, R.R., Doshi, H., Dunnett, N., Gaffin, S., Köhler, M., Liu, K.K.Y., Rowe, B. (2007) *Green Roofs as Urban Ecosystems: Ecological Structures, Functions, and Services*. BioScience Vol. 57, No. 10. http://www.scribd.com/doc/35863149/Green-Roofs-as-Urban-Ecosystems.
[117] Greater London Authority (2009) *The London Plan: Spatial Development Strategy for Greater London (Consultation draft replacement plan). Greater London Authority*. Available at www.london.gov.uk.

covering one face of Ateliers Jean Nouvel's Musée du Quai Branly, in Paris, and a lush, vegetated wall that is part of a building at the Vancouver Aquarium, in Canada. [118] Green wall will provide a variety of ecosystem services; see Table C.5 (Appendix C).

2.3.2.3 Green Corridor

It is meant by urban green corridor, besides the significance of green spaces for preserving air corridors, they serve as separating elements in the landscape network. The division function of air corridor must be well understood and have distinct consideration in landscape planning process. "Sufficient proportions of green space have a climate-regulating function. In general, the provision of meadows with a thin cover of trees and shrubs is especially favorable." [119]

2.3.2.4 Greenway

The origin of greenways goes back to the 19th Century park-planning era. Only the last decade of the 20th Century has emerged to become the foundation of the greenway planning movement. [120] Greenways are corridors of land recognized for their ability to connect people and places together.[121] Green way is a corridor of undeveloped or park land that follows a natural feature (like stream valley, floodplain) or between urban centers. Normally, greenways offer a pedestrian network that joins neighborhoods and parks in all parts of a community.[122]

2.3.3 Urban Forest

Heske (1938) described the function of urban forestry as an asset of forest for the 'spiritual and bodily hygiene' for urban citizens instead of fiscal return[123]. It is defined as forest or an assortment of trees or suburb that cultivate within a city, town. Generally it can contain any type of woody plant vegetation growing within and around built-up areas. See Table 2.1, for its ecosystem function, and Table C.4 (Appendix C) for climatic services that it provides.

2.3.4 Ecosystem Services of Vegetation

When it comes to quantifying green planning, the available area and the function that should be performed is fundamental in selecting the type of vegetation. Type of vegetation together with type and size of green area will influence the ecosystem function of green structure and eventually the built environment. See, Table C.4 (Appendix C) that illustrates climatic service of different type of vegetation. Climatic circumstances, particularly rainfall and extreme temperature events, might limit the usage of some types of species or impose the irrigation-mode for horticulture. Due to the water scarcity or and avoidance of ground water as source of irrigation. Indigenous plants are usually considered perfect picks for landscapes due to their adaptation capacity to climates, and the native stress-tolerant floras. Furthermore, the biodiversity and nature conservation policy mostly prefer the use of unique native and illustrative plant communities.

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[118] Gonchar, J. (2010) *Vertical and Verdant, Living Wall Systems Sprout on Two Buildings, in Paris and Vancouver*. http://archrecord.construction.com/features/digital/archives/0702dignews-1.asp accessed on 5-7-2010

[119] Ministry of Economy Baden-Württemberg in cooperation with Environmental Protection Department of Stuttgart. (2008). Climate Booklet for Urban Development Online.

[120] New England Greenway, *history of Green way*, http://www.umass.edu/greenway/Greenways/2GR-his.html.,

[121] Greenways Incorporated (2007) *Greenway Planning and Design*, http://www.greenways.com/greenwaydefinition.html

[122] Google, *Definitions of greenway on the Web*, http://www.google.com/search?hl=en&defl=en&q=define:greenway&sa=X&ei=UfMhTSuEIDqUr6SOCQ&sqi=2&ved=0CBIQkAE

[123] Konijnendijk, C.C., Nilsson, K., Randrup, T B. & Schipperijn, J. (2005) *Urban Forest and Trees*. pp93.

2.4 International Example[124]

The London Plan 'Spatial Development Strategy for Greater London' in section five London's Response to Climate Change policy 5.10 urban greening and policy 5.11 green roofs and development site environs are adopted as part of 'London Climate Change Adaptation Strategy'.

Policy 5.10 urban greening, include two main strategies the promotion and sustenance urban greening, for example novel planting process in the public area (streets, squares and plazas) and GI. Also upsurge the pervious and green surface cover in the 'Central Activities Zone' by more than 5% by 2030, and by 10% by 2050 compared to baseline state. The former strategy includes a framework to plant 10,000 street trees followed by the ambition to plant an extra two million trees in London by 2025. At the planning level it is stated development proposals should integrate GI. Features that can give rise to the greening framework, contain "tree planting, green roofs and walls, and soft landscaping".

Two main tasks have been identified to achieve the above policy , first the identification of areas where soft GI can make a specific influence to mitigate the impacts of global warming, namely the urban heat island second, the research conducted in the LUCID programme ('The Development of a Local Urban Climate Model and its Application to the Intelligent Design of Cities') is working in the direction of delivering information on cooling down the temperature in London that can be attained by adding diverse kinds of urban greening.

Policy '5.11 green roofs and development site environs' includes developed proposals that shall be elaborated to comprise "roof, wall and site planting, especially green roofs and walls" anywhere feasible. In the aim to deliver the objectives of climate change adaptation plan (i.e. aiding cooling), sustainable urban drainage management, climate change mitigation measures (i.e. aiding energy efficiency), biodiversity enhancement, accessible roof space, enhancements to appearance and resilience of the building operation and food growing processes.

[124] Greater London Authority (2009) *The London Plan: Spatial Development Strategy for Greater London (Consultation draft replacement plan).*

3 Methodology

3.1 Research Conceptual Framework

This section explain the approach in which overall framework of the investigation is conducted to achieve the objectives or accomplish the task. The scope of this investigation follows a systematic approach of data collection, analyses and result interpretation with developing alternative concept. The overall framework of the study is represented graphically in Figure 3.1.

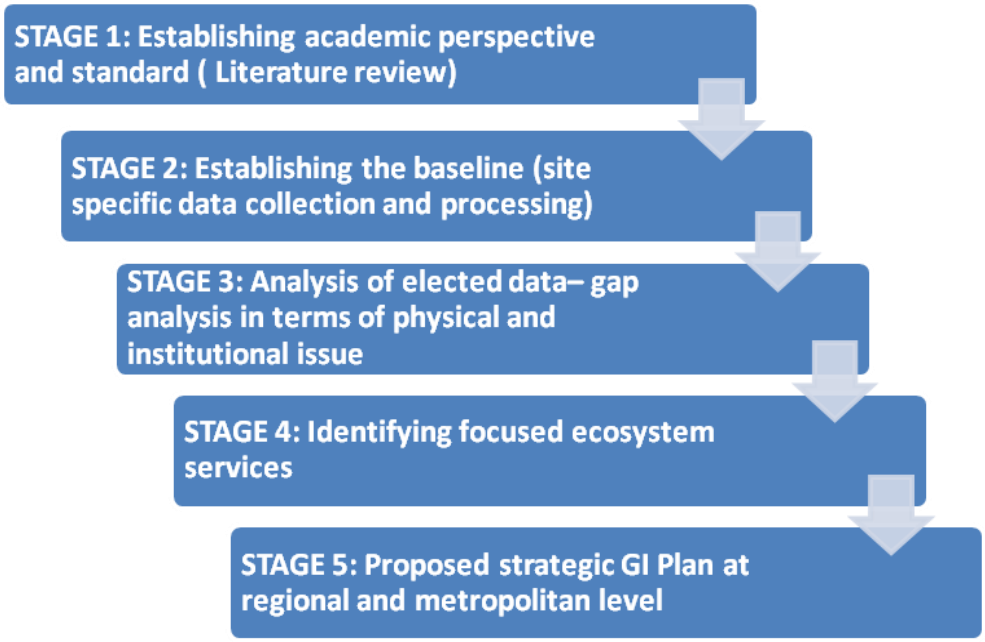


Figure 3.1: Research conceptual framework

Source: Author, 2010.

3.2 Data Management

3.2.1 Data Source

In the early stage the scope of investigation divided between two main poles. Establishing academic perspective and establishing the site specific baseline. In which both conducted by data collection. Both type of data acquisition method have been used.

- **Primary data acquisition:** is capturing data directly from the source. This carried out by site survey and Institutional survey.
  Site survey conducted to get physical and non-physical data about area particularly CSC. This is so important in planning concept for developing spatial impression. Institutional Survey includes survey to the respective institution and organization for collecting data. Semi structured interviews were also conducted with the stakeholders.
- **Secondary data acquisition:** is capturing data from secondary source independent from the site. Different sources like books, researches and internet can be used.

Accordingly the gathered data can be classified within two main category analogue and digital data, see Figure 3.2.

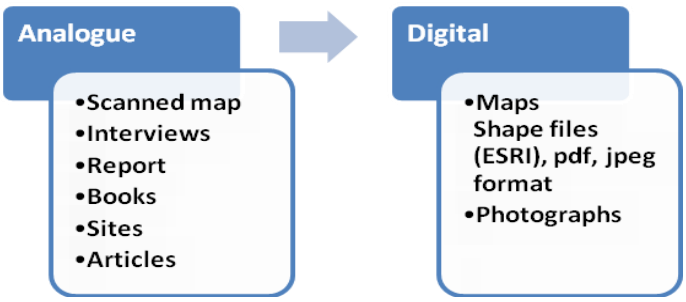


Figure 3.2: Data type calcification

Source: Author, 2010.

3.2.2 Data Quality

Data quality has been defined as "Degree to which a set of inherent characteristics fulfils requirements (DIN EN ISO 9000:2000)".[125] Deriving from this definition, forming data base to fulfill requirements of this investigation was far beyond completion. Since one month visit to the study area were not sufficient to gather all necessary data, this regardless of the fact of availability and quality of data that have been gathered. The later problem is common for developing countries in general, but due to specific political and administrative situation of the study country this reflected more. That led to the discussion of reliability and quality of data. Both 'quantitative quality information' and 'Non-quantitative quality information' come under question. In which the problems of completeness, logical consistency, position and temporal accuracy recorded under the former category and also the usage and purpose is recorded under the latter category.

To sum up, within the complete data set structure so many part were missing in a way it formed a puzzle matrix. To produce missing part either descriptive approach is adopted or data have been formed. The latter conducted by author through digitizing updating and sampling method. A set of assumption is carried out based on local specific facts by conducting "inelegant guesses" concept to develop a data set that fulfills requirement. Developing land cover map can be giving as an example. This layer were developed by digitizing the public green areas in the CSC and for establishing private green area assumption made based on digitizing certain samples. Also land use of the CSC belonging to 2006, author updated some part important for this investigation.

Although the data set is established, but the possibility of errors cannot be overcome particularly those related to processing errors and spatial variation errors. In which that may source from digitization process of analogue maps, and different age of data.

3.2.3 Data Structuring

Since three different special levels define the working environment, setting a clear spatial structure of data processing was necessary that is consequently identifying the level of detail. The first special level is national level in which Iraq have been taken in both local and international context. Deriving from national context, the regional context has been identified. Since author applying 'borderless community' concept, that is why in identification of CSR based on the natural classification of the country like agro ecological, and etc, secondly the availability of data for the selected area.

[125] Metzner, M. (2009). Data management and Analysis, *Functional Requirement Analysis*. Lecture.

The third level, that have been dealt with in more detail is city or metropolitan level. A vital decision was to outline the physical boundary of the area under investigation. There was no clear method to identify the exact area that will be used in analysis. Since urban area are defined in different ways. The author depended on two examples. The first one is the case study about the Urban Forest Resource in European Cities, in which it the concept of "equal distance zones around the city center" to identify urban area for different European city to compare is used. [126] In addition to that, the similar approach in North West region in Britain where, GIP concept is widely developed. So the method for identifying physical boundary of investigated area derived by applying "a substantial buffer to any given physical or political boundary (such as the edge of a town where the buildings stop) because GI outside is likely to be performing functions that benefit the inhabitants inside".[127] Accordingly the city area classified to area inside 60m ring road and landscape scale.

3.2.4 Data processing

Since the probabilistic approach is forming the base for investigation (particularly at a metropolitan scale) in which the developed concept could use as model for implementation. [128] That is why data processing stage carried out with this perspective in mind, regardless of data quality problems.

The choice of Geographic Information System technology was due to the fact of multidimensional combination of data and layers, different spatial level, and different source and age of data. To create a comparable data set by using GIS as a tool for processing was the only practical solution. Two main concepts have been conducted by using GIS technology mainly: ***Inventory*** or green printing' or 'green infrastructure mapping' utilizes GIS technology to map the natural and cultural resources of an area. In addition to GIS Arc View 9.3 also AutoCAD 2008 has been used for digitizing and mapping. A step by step structure has been used to create GI map at both levels, see Figure 3.3. ***Analysis*** GIS Arc View 9.3 has been used, to overlay different layers. Author depended on both raster and vector data analysis and processing, in this regard different analysis tool have been used.

Figure 3.3: GI mapping conceptual framework

Source: Author, 2010.

[126] Mander, U. et al (2007) *Landscape Tomorrow : Multifunctional Land Use*. P1, P37.
[127] North West GreenInfrastructure Unit (2009) A Green Infrastructure Mapping Method, http://www.greeninfrastructurenw.co.uk/.
[128] Mady, C. (2005) A Dynamic Network of Heritage Landscapes: one Mediterranean Perspective. Master Thesis, MIP University of Stuttgart.

4 Natural and Cultural Resource in Case Study Area

4.1 Scope of Case Study Region

4.1.1 Natural Resources

4.1.1.1 Topography

The relation between land cover to elevation help to have better understanding to the vegetation cover in the CSR, since it is directly related to the type of tree species that grow at certain altitude. Furthermore the interrelation between slope and vegetation cover which help to identify areas with high degree of erosion and consequently the suitable type of vegetation.

The topography of the CSR varies between 250- 3600 m. The Zagros Mountain chain denotes the 'southern, Asian branch of the Alpine geosynclines'. Topographically the CSR have been divided in to three main zones: The mountainous zone, semi-mountainous zone and plain zone. The mountainous zone is consisting 27% of the total area of CSR, within 3000- 1000m high by slope of 40 m/ km. The chain takes a curve shape starting in the NW direction extending to E then to SE of the CSR. This zone encloses so many fertile planes like Sulaimaniyah, Shahrazoor and Raniya plain. The semi-mountainous zone is consisting 65% of the total area of CSR, within 1000- 300m high by slope of 18m/ km. It characterized by different geographical patterns starting from mountains, hills, valise and plains, namely Hamrin Mountain and Hamrin, Erbil, Sinjar and Diebage plane and hzbat Kirkuk. The plain zone is consisting 8% of the total area of KR, within 40- 50 m high however this typology doesn't include within boundary of CSR except for a very small area at very extreme SE. [129]

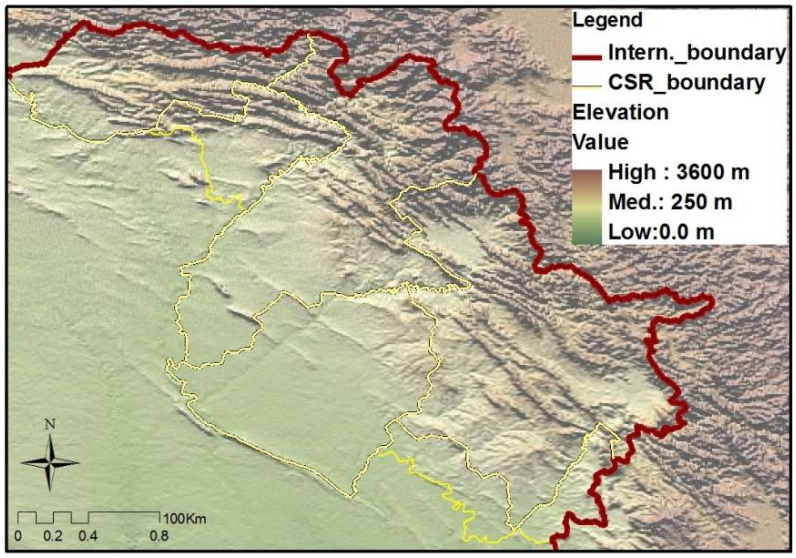


Figure 4.1: Topographic map of the CSR

Source: Author, 2010, from NGA data.

[129] Buday, T. & Jasim, S.Z. (1987) *The Regional Geology of Iraq: Tectonism, Magmatism and Metamorphism II*. Vol. II. Pg.445.

4.1.1.2 Geology

The importance in dealing with this layer layers in its direct relation to water resource in the area particularly the ground water resources that is why a the author will give an overview. CSR geologically "is a part of the extensive alpine mountain belt of the Near East. The Taurus-Zagros belt developed during the collision of Afro-Arabian continent with the Eurasian continent"[130]. The strata had been strongly folded during the late Tertiary times to form a series of NW to SE trending hills and mountain ranges. Tectonically CSR territory can be subdivided into Thrust and folded zones (Low folded and High folded)[131]. Topographically these tectonic zones are known as the high mountains, low mountains and mixed mountainous and hilly area respectively.

The geological structures of these three zones are "imbricate with recumbent folds and thrust faults, high amplitude anticlines and synclines and low amplitude synclines and anticlines"[132]. Similarly, is leading to the development of three major morphologic units, followed by typical landforms: "anticline ridges, structural denudation hills and slopes, and fluvial accumulation plains", see Figure 4.2.

The thrust or nappe zone occupies strips of KR territory along the borderline in N and NE. "It is a zone of intensive mobility and differentiation that contains geological formations from pre-Triassic and Jurassic to late Tertiary times". This area characterized by having "older geological formations laid above of newer ones, which is quite uncommon" [133]

High Folded Zones: In the High Folded zone, the earliest formations dating back to the Middle and Upper Jurassic. Its development belongs to Triassic and Eocene era, their Tectonic characteristic is "the occurrence of long linear double plunging folds, with anticline structures such as mountain ridges and intermountain valleys in synclines between them. Intensive uplifting and folding of the sedimentary complex sequence are the result of Alpine organic poly-phase deformation". The high folded zone contains outcrops of lime and marl or shale. [134]

Foot hill zone or Low Folded Zones: Its development belongs Eocene up to recent time, characterized by fluvial deposits and alluvial deposits These Quaternary sediments are the dominant geologic units and are the youngest formation and composed of different types of terraces around the valleys. They consist of a mixture of clay, sand and pebble with various thicknesses. They are covered with a thick layer of fine soil in the broad valleys or in the plains and with a thin layer of coarse material on the gentle slopes in front of the anticlines. Examples of such plains are Sindi, Hawler, Qaraj, Sinjar, Sharazoor and Bakrajow plains. [135]

Various regional faults, succeeding the longitudinal tectonic trend, or occasionally crosswise to the core structures, regulate the river valley direction and favored groundwater paths. "The foothills in the front of the Zagros Mountains are composed of beds of gravel, conglomerate and sandstone; all these products accumulated during the erosion of the mountains. The area is somewhat folded in a

[130] Giopolicity, International Mangement Consultancy Group (2010) *Managing the Tigris Euphrates watershed: The challenges facing Iraq*. http://www.geopolicity.com/publications.php?page=5

[131] Giopolicity, International Mangement Consultancy Group (2010) *Managing the Tigris Euphrates watershed: The challenges facing Iraq*.

[132] Khursheed, S. (2003) *Study of Swell-Shrink Potential of Soils in Sulaimani governorate and its Surroundings*. PhD. Thesis

[133] Jalal, J. (2008) *Natural Resources and Its Utilization for Agricultural Development in Sulaimany Governorate*. PhD. Thesis

[134] Guest, E. (1966) *Flora of Iraq*. Vol. 1.

[135] Layla, A. (2004) *Geographical Analysis of Soil Characteristic and Problem in Erbil Governorate, and the Degree of Land Fertility*. PhD. Thesis.

later phase of folding, thus forming a fairly hilly landscape, also with low parallel hill ridges and rather extensive valleys and plains, in which various streams have cut their valleys" [136]

The most important feature is karstification which is the product of erosion in some limestone rocks. The karst of the northern CSR is about 35% of that region. This karst has relatively different characteristics compared to other karstic Euro-Asian mountainous chains molded through Alpine organic cycle classic bigger surface formations such as sinkholes or dolines are not as common in the KR region. Historically the main cycle took place in Paleocene period continued to Oligocene-Miocene period and still active up to now. Karstification Geosynclines system in CSR, is stimulated by consequence of specific tectonic setting and climatic conditions of the region. [137]

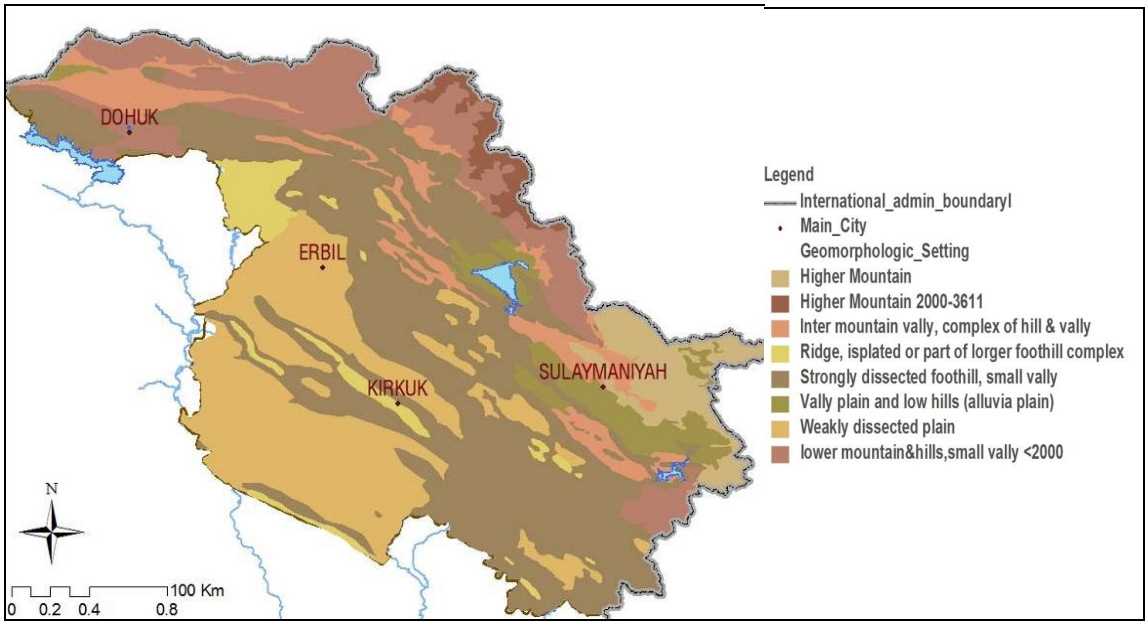


Figure 4.2: Geomorphologic formation of CSR

Source: Degitized and modified from FAO, 2003.

4.1.1.3 Hydrogeology

Due to water scarcity problem in the country under the provision of climate change lead the author to deal with this layer. In general, the location and movement of groundwater are largely determined by the location of geological formations. As mentioned in previous section the geological faults is controlling both river orientation and groundwater pathways also karstification that characterize the CSR. This geological formation developed surface and underground karstic morphology, see Figure 4.3.

[136] Jalal, J. (2008) *Natural Resources and Its Utilization for Agricultural Development in Sulaimany Governorate*. PhD. Thesis
[137] Stevanovic, Z., Iurkiewicz, A. & Maran, A. (2009) *New Insights into Karst and Caves of Northwestern Zagros Northern Iraq*, http://carsologica.zrc-sazu.si/downloads/381/7Stevanovic.pdf

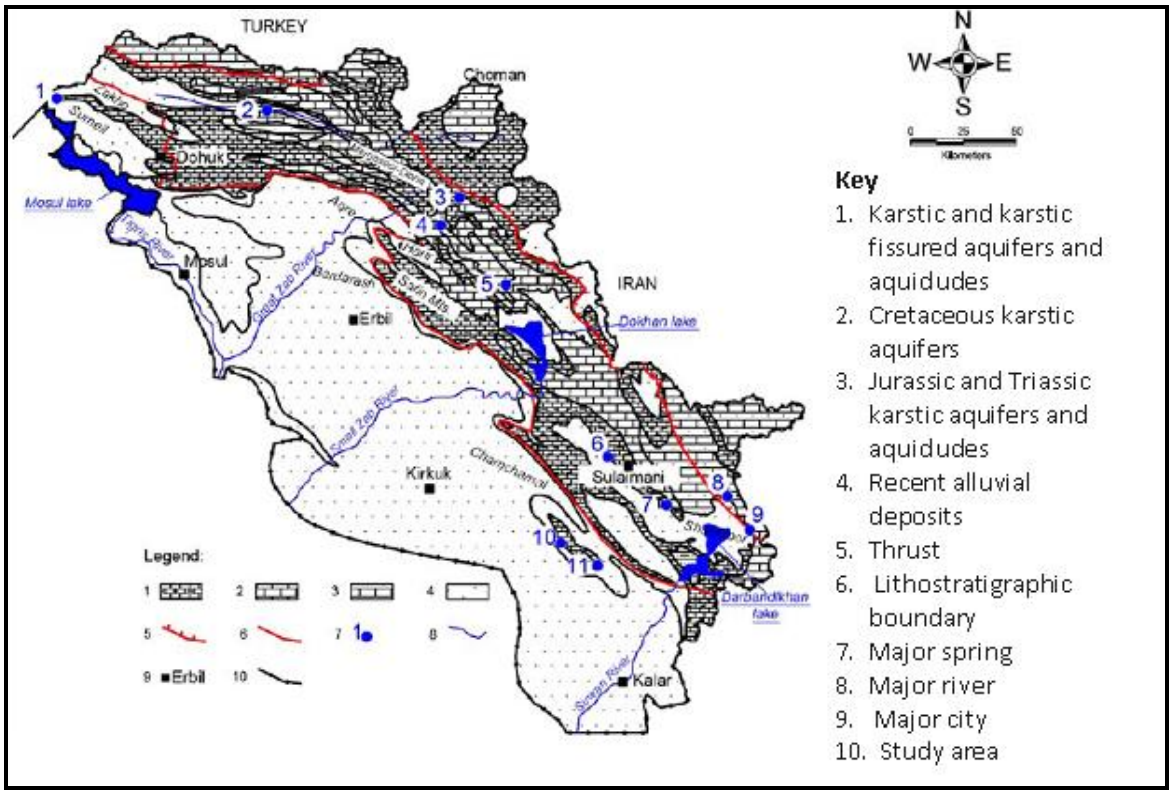


Figure 4.3: Hydro-geological provinces and aquifer systems of North Region

Source: Stevanovic e, Z. et al, 2009.

Three main aquifer systems are considered of great significance for ground water use in CSR. They characterized by medium to large ground water reservoirs and vary in depth from 1- 10 km. [138]

• Karst aquifer "Bekhma" of Cretaceous/ Paeocene age formations developed in carbonate limestone and dolomites. This aquifer is widespread in northern and central parts of CSR

• Fissured-karstic "Pila Spi" aquifer at central-southern parts of CSR (Eocene limestone including carbonates);

• Intergranular "Bakhtiari aquifer (including overlaying Pleistocene terraces and recent alluvium deposits) mostly at southern parts of CSR. [139]

"The limestone aquifer contributes large volumes of water through a number of springs. The alluvial aquifers contain large volume reservoirs and annual recharge is estimated at 620 million m3 from direct infiltration of rainfall and surface water runoff."[140]

However up to present time there is no comprehensive mapping of ground water recourse neither in KR nor in the Iraq, but more than 13 main groundwater basins diagnosed in KR. [141]Generally, the groundwater is deep and the depth exceeds 15 m in most cases (but in certain areas is at a depth of

[138] Stevanobic, Z., Markovic, M. & Iufkiewic, A. (2003) *Climate, Hydrology, Geomorphology of Northern of Iraq: Hydrology of Northern Iraq*. Vol. 1. 2nd Ed.

[139] Coalition Provisional Authority (CPA) (2004) *Master Plan and Design of Sewage Network and Treatment Plants for the Cities of Dohuk, Erbil and Sulaimaniyah: Sulaymani Final Master Plan.* Vol. 1 of 3, Main Report.

[140] Food and Agriculture Organization of the United Nation (FAO) (2008) *Aqua-stat, Iraq, Geography Climate and Population,* http://www.fao.org/nr/water/aquastat/countries/iraq/index.stm.

[141] Jalal, J. (2008) *Natural Resources and Its Utilization for Agricultural Development in Sulaimany Governorate*. PhD. Thesis

a few meters below the ground surface). Furthermore they are confined by overlying impermeable strata. When they intersect the land surface they appear as springs at many locations.[142]

4.1.1.4 Soil

In dealing with green dimension, one of the basic layers is soil, to develop view of feasibility of the green concept. The area is characterized by different type of soil, with different depth layer due to the geographical and climatic condition of the CSR. Nevertheless according to the available historical data about forest cover and vegetation cover it is a good evidence that the soil fertility in general ranging from good to excellent in the plains and valleys, like soils of Sharazoor plain can be classified under Xerolls great group. See

Figure 4.4 represent the map of the relative classification of potential soil suitability for agriculture use.

Generally the mountainous topology can be described as rough broken and stony lands. So the soil layer is very thin with a two common groups of soil. “Rendolls, the soils that have dark brown to black granular surface layer of 15–30 cm depth overlying different kinds of limestone. They are usually found on the northern aspects of the mountain slopes. Xerorthents, the soils of about 15 cm in most cases overlying rocks, limestone, sandstone or shale”. Valley and plain typology can be categorized as good soli type, with depth ranging from 15-50 cm and organic content of 1-4%. While the valleys in the mountain region are synclines, they are filled with gravel of Bakhtiari formation, covered by several meters of fine textured soils.[143]

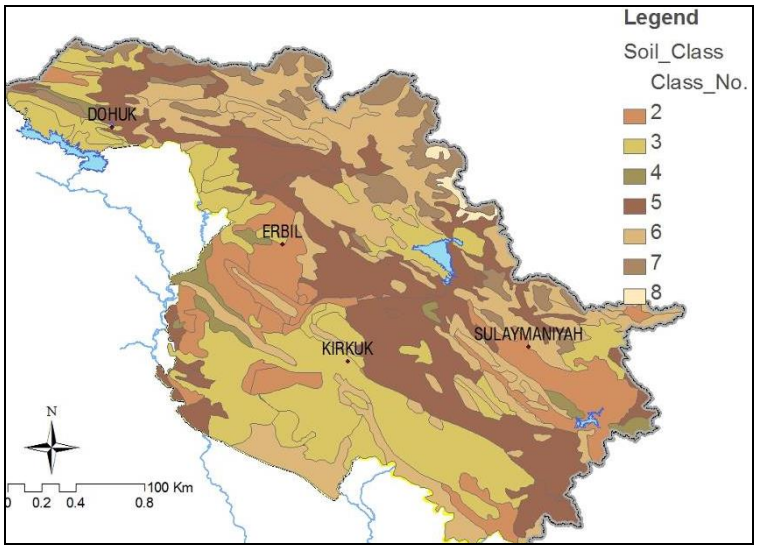


Figure 4.4: Soil map of CSR

Source: Digitized and modified from Sulaimany University, College of Agricultural.

According to Buringh and the recent study conducted in the KR the total suitable land for agricultural activity is estimated by 757000 ha in KR. See Figure 4.5 illustrated the different degree of suitably for different use corresponding to their area.

[142] Khursheed, S. (2003) *Study of Swell-Shrink Potential of Soils in Sulaimani governorate and its Surroundings*. PhD. Thesis.

[143] Khursheed, S. (2003) *Study of Swell-Shrink Potential of Soils in Sulaimani governorate and its Surroundings*. PhD. Thesis.

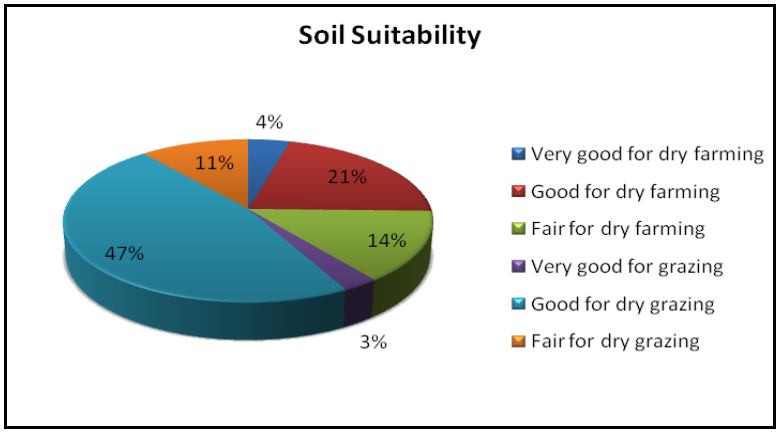


Figure 4.5: Distribution share soil suitability in Kurdistan Region

Source: Author, 2010.

4.1.1.5 Land cover

Land cover is the basic identification of biodiversity of species and wild life at any ecosystem. Also it has relation to aquifer and surface soil management. That is why it is of essential importance to illustrate this layer clearly. Land cover was developed by author depending on the pdf file format from United Nation site in parallel to the descriptive information about CSR. Different typologies have been taken into consideration according to degree of importance for the studies theme.

- **Woodland**

  - **Forest**

Historically the mountain forests area is estimated by Chapman by around 20000 km^2 that is around two-thirds of the whole mountain area in the CSR. "About 50% of the mountain forests are of good stock and may be regarded as productive forests; the remainder represents degraded scrub with a sparse stock of bushes".[143] The forests in the CSR growing at altitudes of 700-1400 m above sea level have been reduced to open woodland. Native tree species is estimated by 20 types. Zohary, 1946 classified four forest zones in Iraq, The CSR can be classified accordingly to three main zones as follows:

Mountain forest zone: The northern mountain zone occurs between the 500 m and 3000 m contours and lies within the forest region within precipitation rate between 450-1200 mm. Also, the area above 800 m elevation of Sinjar Mountain is included in this region. The extent of mountain forests is estimated to be about 20000 km^2 which is about two-thirds of the mountainous region. Until 1950, half of this area was productive forest. [144]

Steppe zone: The steppe zone covers the territory located between the Hamreen range up to the foothills and lower part of the mountain zone. The Steppe region can be divided according to the altitude and the amount of annual precipitation into two distinct zones, the semi moist-steppe zone, while the CSR mostly covered by this category with annual rainfall of 450- 650 mm. It extends across

[144] FAO (2008) *Forestry Country Information, Iraq*, http://www.fao.org/forestry/country/18314/en/irq/.

the foothills and mountain slopes at elevations of 400-600 m above sea level. Also the moist-steppe zone lays with an elevation of more than 600-900 m with an annual precipitation of 650-850 mm. [145]

Riparian forest: This category of woodland lies both within and outside the forest zone. It basically starts at the mountain streams and follows the waterways from the mountain forest zone through the steppes. The dominant tree species include poplar and willow. FAO reported a drastic reduction of this type of forest in the area from 20000 ha to insignificant area currently.

- **Shrubs**

This category can be classified within two vegetation zones according to FAO,

Alpine vegetation, thorn-cushion zone that characterized by the presence of "tall thistles, *Cirsium spp*. and *Cousinia spp*., and the giant yellow *Prangos ferulacea.* Also Low spiny tufted cushions of *Onobrychis cornuta* and *Acantholemon* spp. between the *Astragalus* bushes are a conspicuous feature of the vegetation of this zone". It has an altitude of 1800- 3000 m, which receive 1000-1250 mm of precipitation annual, mostly in the form of snow.

Dry steppe zone vegetation is covers areas with annual precipitation of 200- 350 mm and grows at an altitude of 100- 350 m. This is a belt like of grassland and short perennial shrubs; include "*Artemisia herba-alba* and *Achillea conferata*. There are also many spring weeds such as *Salvia compressa, Astragalus mossulensis, Gladiolus segetum* and *Muscari longipes*". This typically can be found in Jabal Himreen area at the SW direction of CSR. [146]

- **Open land** [147]

This typology consist the wide are of The CSR. It covers cultivated, cropland, grassland, bare land and grazing lands. The agricultural potentials of the mountain slopes and the hilly area are limited. The limited factors are soil depth, slope exposure, rockiness and stoniness. Conversely the soils of the plains are more uniform and from agricultural standpoint, are very important.

Overall, dry farming is practiced to a large extent throughout the study area, since the source of irrigation water is limited during the summer season; a small fraction of the total area is brought under irrigation farming. These sources include springs of various discharges, shallow and deep wells and perennial streams. The CSR can be divided into three agro-ecological zones, correspondingly:

Upland plains and valleys agro-ecological zone: This zone is located in the intermountain regions of the plains (Figure 4.6). The annual rainfall varies from 550- 900 mm. Mixed farming cultural practices systems occupy most of the plains and valleys. Cropping system consists of wheat, commonly, durum and barley allocation. Natural grazing land consisted of mostly treeless areas on slopes with southern aspects and forest of medium conditions. Unlimited annual water resources of the zone, is adequate to transform all the rain fed agriculture land into irrigation.

The high altitude hills and mountain zone: The northern and eastern border areas with Iran are characterized by steep landscapes in the high altitude of 1800-3600 m.

Lowland zone: Consists of land in the southern part of the CSR, altitude of the annual rainfall is between 250- 600 mm, and topography is relatively flat between 300- 600 meter. The region supports a mixed dry land farming system based on rain fed. There are strong interactions with pastoral systems. The vegetation of the rangeland in the area provides a good pasture to the grazing

[145] Jalal, J. (2008) *Natural Resources and Its Utilization for Agricultural Development in Sulaimany Governorate*. PhD. Thesis

[146] FAO (2008) *Forestry Country Information, Iraq*, http://www.fao.org/forestry/country/18314/en/irq/.

[147] Chapman, G.W. (1948) *Ten years of forestry progress in Iraq.* FAO, Corporate Document Repository, Forestry Department, http://www.fao.org/docrep/x5391e/x5391e03.htm

animals. The quality of the pasture land depends on the type of vegetation species and their intensities, such as legumes and grasses families. [148]

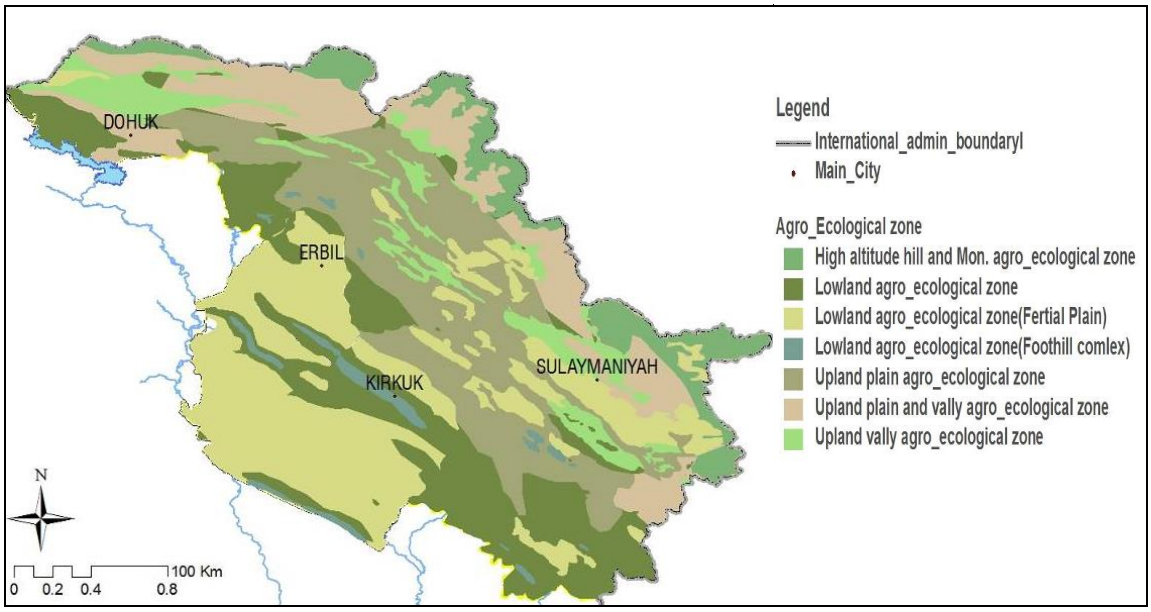


Figure 4.6: Agro-ecological zoning of Kurdistan Region

Source: Digitized and modified from FAO, 2003.

- **Orchards**

The CSR is a rich area of diversity for several stone fruits, both domesticated and bare. The orchards mostly lay in lowland agro-ecological zone. It consists of reasonable amounts of vineries, figs, pears, peaches, apricots, walnuts, almonds, wild sumac of Rhus coriaria, date palm, pomegranate, pistachio, olive, apple, plum and oaks of all the three local oaks species. These products can cover the KRs local markets adequately. See Figure 4.7shows orchard areas in CSR.[149]

- **Surface water**

Different layers like river, lakes, stream, well and Karez are identified. The integrity between species diversity and human settlement is directly related to riparian typology, so it is important to have an overview about water resource in the CSR.

The mountain chains were dissected by many large or small consequent valleys, the largest one is that in which the Lesser Zab and Great Zab Rivers flow. [150] The Zab Rivers flow from the E to the W in the region. The Tigris River move in to Iraq from KR with the upstream flow from Turkey. Also Sirwan or Dyala River flows from E to S of the region.

Great Zab: is main largest tributary of the Tigris River. The drainage basins of the Lesser Zab are located in Turkey (Wan), then entering KR at N. Approximately 300 km of the river's course are

[148] Jalal, J. (2008) *Natural Resources and Its Utilization for Agricultural Development in Sulaimany Governorate*. PhD. Thesis
[149] Nova, W. & BlueFox Geomatics, Ine (2005) *Sulaimaniyah Urban Forestry Report*.
[150] Jalal, J. (2008) *Natural Resources and Its Utilization for Agricultural Development in Sulaimany Governorate*. PhD. Thesis

located within KR with drainage basin and catchment area of 62%. Its average total annual discharge is around 13.2 billion m³ water, contributing of 28 % of the total Tigris River.[151]

Lesser Zab or Little Zab: is the second largest tributary of the Tigris river. The drainage basins of the Lesser Zab are located in Iran, then entering KR at E of Qaladiza. Approximately 367 km of total 400 km is located in KR, with the total catchment area of 71.8 %. Its average total annual discharge of the Lesser Zab River is 7.3 billion m³ water, contributing of 15.5 % of the total Tigris river discharge. [152]

Sirwan River or Diyala River: It is the third largest tributary of the Tigris River. The drainage basins of the Sirwan are located in Iran then entering KR at Sulaimaniyah governorate. The total length of Sirwan River is 368 km. Its average total yearly discharge of the Sirwan River is 5.7 billion m³, thus contributing an amount of 13.57% of the total Tigris river.

Beside these revisers there is turbidity for main rivers like Darbanbasara tributary. It is a small tributary of Auzim River with their watersheds is located in Qaradagh sub district, Sulaimaniyah governorate. The total annual capacity is estimated to be around 110 million m³. [153]

Dokan Lake or Dukan Lake: is the largest lake in KR. It is located NW of Sulaimaniyah and is a reservoir created by the construction of a hydro-electric dam. The Dukan Dam is located on the Little Zab. The Dokan water reservoir covers 270 km².[154] **Darbandikhan Lake:** It is the third largest lake in KR. It is located 68 km SE of Sulaimaniyah and is a reservoir created by the construction of a hydro-electric dam. The Darbandikhan water reservoir covers 121 km².[155] While **Mosul Lake:** is the largest dam in Iraq. It is located on the Tigris River in the SW of Duhok city in KR. It is forming the border line between KR and Iraq. No exact data available about the catchment area but nevertheless a considerable percentage laying in NW part of KR. [156]

Springs: There are several hundred of springs and Ghanats (karez) in CSR which have been supplying the cities and towns with water and used for the cultivation of orchards and the production of vegetables for the villagers. Karez (except for infiltration Karez), spring, spring tunnels, and surface-cut spring channels are the underground water that is come up to surface due to natural pressure. It is estimated that more than 12100 springs and 2720 Karez of all type are exist in the CSR. The snow on the high mountains is acting as small reserve for supplying spring and streams during dry seasons such as summer.

To show the land use map of the region including vegetation surface and water surface in a connection to existing buildup area, see Figure 4.7.

[151] Wikipedia, *Greater Zab*, http://en.wikipedia.org/wiki/Great_Zab

[152] Wikipedia, *Little Zab*, http://en.wikipedia.org/wiki/Little_Zab

[153] Jalal, J. (2008) *Natural Resources and Its Utilization for Agricultural Development in Sulaimany Governorate*. PhD. Thesis

[154] Wikipedia, *Little Zab*, http://en.wikipedia.org/wiki/Little_Zab

[155] Jalal, J. (2008) *Natural Resources and Its Utilization for Agricultural Development in Sulaimany Governorate*. PhD. Thesis

[156] Source: http://en.wikipedia.org/

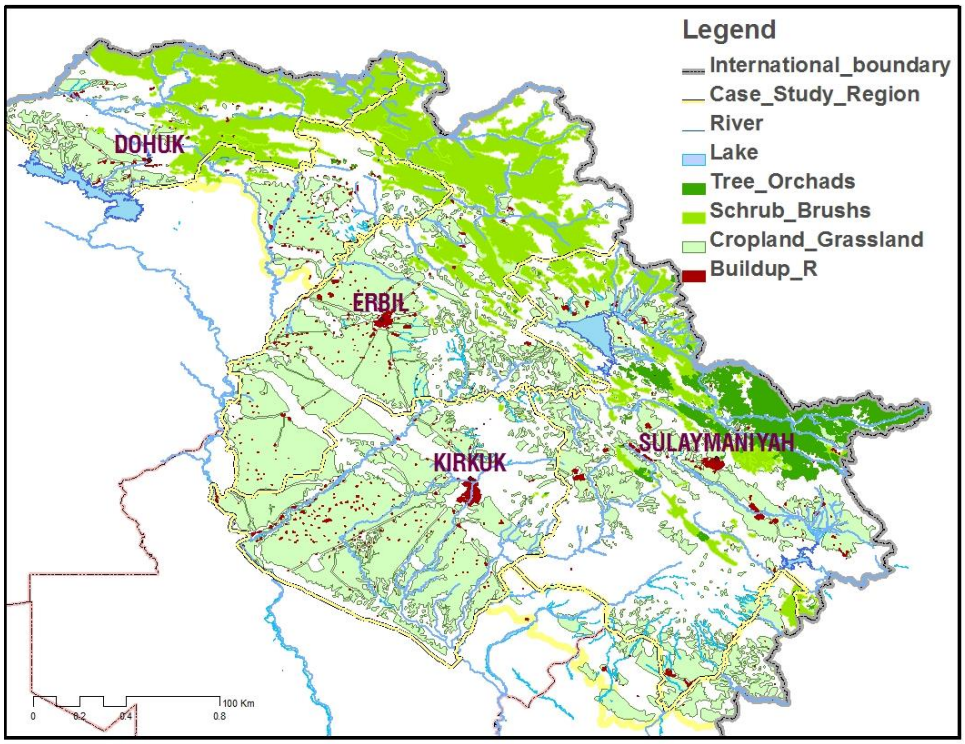


Figure 4.7: Land cover map of CSR

Source: Author, 2010, digitized and modified from Iraq land use map by IAU.

4.1.1.6 Watersheds

At national scale, the area of the Tigris River Basin is around 253 000 km^2, which is 54% of the whole basin area[157]. The CSR is bounded by four main rivers. All are originating from neighboring country Iran and Turkey, thus, the total basins area are larger than the investigated area, See Figure 4.8.

Regarding their drainage system "The Border Folds zone, characterized by an anticline/syncline system with a variable trend (from alpine in the centre-SE to E-W in the NW), greatly influences the drainage pattern". Moving toward SW side of the CSR, flat alluvial plain is dominated typology, the "drainage pattern is definitely dendritic and parallel, although some pinnate examples with long tributaries are still present in connection to folded areas."[158]

[157] Lightfoot, D. (2009) *Survey of Infiltration Karez in Northern Iraq: History and Current Status of Underground Aqueducts*: *A report prepared for UNESCO-IQ/2009/SC/RP/1.* Oklahoma State University, http://www.iauiraq.org/reports/UNESCO_Karez_survey_report_FINAL.pdf

[158] Food and Agriculture Organization of the United Nation (FAO), Natural Resources Management and Environment Department (2003) *Groundwater search by remote sensing: A methodological Approach*, http://www.fao.org/DOCREP/005/Y4639E/y4639e04.htm#TopOfPage

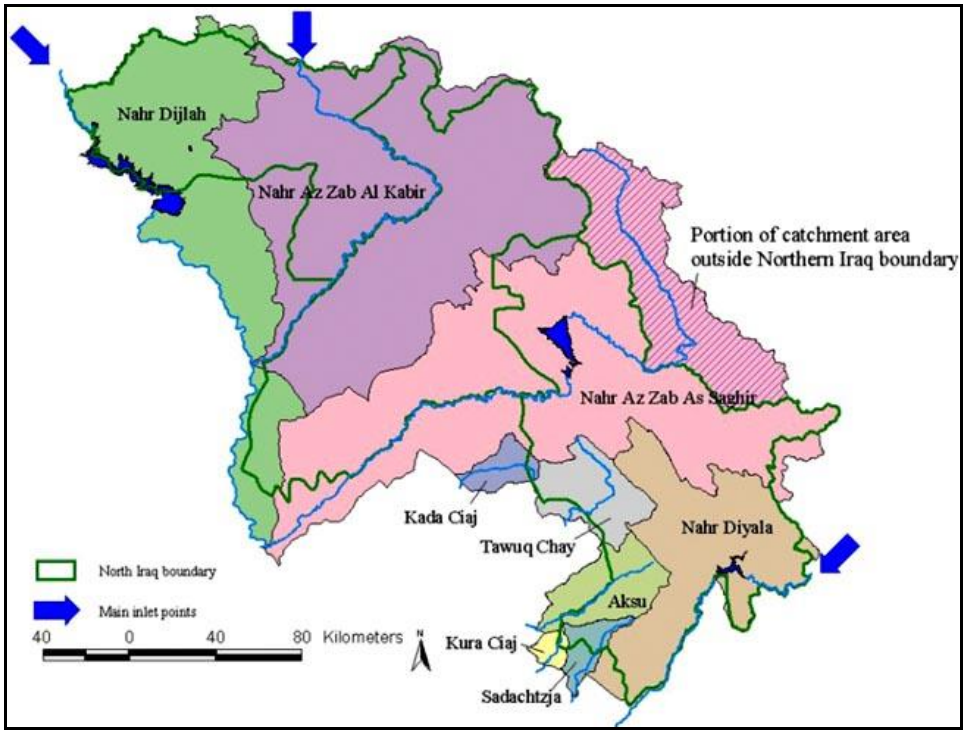


Figure 4.8: Watershed area in CSR

Source: FAO, 2003.

4.1.1.7 Landscape [159]

CSR covers parts of Lower Zagros and Upper Mesopotamia. Zagros Mountains, highly folded dominate rich fertile valleys and villages bending under the high mountains. As Zagros Mountain foothill extends to Upper Mesopotamia that represents a vast rolling plain limited mainly by the sharp valleys of the Tigris River and its main river branches with a number of closed basin. Its altitude varies from 3600- 250 m. with a number of small closed basins. It is worth mentioning that all around CSR is well known of its natural picturesque landscape. See Plate 4.1 some scenic landscape of the CSR.

[159] Stevanovic, Z., Iurkiewicz, A. & Maran, A. (2009) *New Insights into Karst and Caves of Northwestern Zagros Northern Iraq*

Plate 4.1: Scenic landscape in the CSR: Doli Plingian in summer (T), Bamo mountain in spring (BL).Dukan lake in summer (BM) Silava village in summer (BR)

4.1.1.8 Flora and Fauna

Since there is no new inventories available for flora and fauna in Iraq, the author present classification made by some researchers also the survey that made by FAO and Nature Iraq. The flora of the CSR is categorized by 'Guest' under, the Mediterranean and the Irano-Turanian elements. The Mediterranean element for which the great majority of the plants are weeds, mainly present among winter dry farming crops where they flourish side by side with the weeds of Irano- Turanian elements.

Moreover, Guest identified small group of Mediterranean species of trees and shrubs scattered in the CSR, such as:*"Crataegus azarolus, Juniperus oxycedrus, Cercis siliquastrum, Fraxinus syriaca, Platanus orientalis, Thymbra spicata* and some *others*". While Irano-Turanian elements occur all over the foothills and mountains of the CSR, they are mostly the vegetation of the typically steppic. The climaxes being dominated by *hemicryptophytes*, mainly grasses and *chamaephytes*, *dwarf shrublets* in more or less dense groups. " As whole of CSR, which is extraordinarily rich in endemics, and which represent 57% of the species all the Irano-Turanian elements. [160]

The typical flora of **Mountain forest zone** is known as 'Mountain Oak Forest' zone, are characterized as "*Quercus* forest formation of three main categories, *Quercetum aegilopidis, Quercetum aegilopidis-infectoriae and Quercetum infectoriae-libani (Guest,1966).* However, the lowest forest zone is mostly occupied by *Quercus aegilops* associated with *Pistacia khinijuk* and *Rhus coriaria*, while in the middle zone of the oak forest, is occupied by *Q. aegilops* and *Q. infectoria*, but the highest zone of the forest are occupied with both *Q. infectoria* and *Q. libani*."

The climax vegetation of **steep zone** is dominated by "*Pistacia mutica, Pistacia khinjuk* and other small trees. Tree species are rare at the present time since woody trees and shrubs have removed. During the spring it is characterized by the grasses *Poa bulbasa, Hordeum bulbosum* and *Anemone coronaria*". The **riparian woodland** is comprised of dense stands of *Salix acmophylla* and thickets of *Populus euphratica, Tamarix pentendra, T. meyeri* and *T. florida*. A groundcover of riparian herbs such as *Cyperus pygmaeus* and *C. alopecuroides* and tangled clumps of *Rubus sanctus* is common. [161]

[160] Jalal, J. (2008) *Natural Resources and Its Utilization for Agricultural Development in Sulaimany Governorate*. PhD. Thesis

[161] FAO (2008) *Forestry Country Information, Iraq*, http://www.fao.org/forestry/country/18314/en/irq/.

In order to give visual description see Plate 4.2 shows a general overview about the existing flora in the CSR.

Plate 4.2: Riparian woodland combination of (*Populus euphratica, Tamarix pentendra)* at Ahmad_Awa(TL), The new recorded plant *Outreya carduiformis* at Doli Smaquli (TR), The tree *Quercetum aegilopidis-infectoriae at Qradagh (BL)* The endemic plant *Astragalus spinosus* at mangeesh.(BR)

Source: Google photo, 2010.

Since spices are important in terms of both richness and their interdependence, so quality and quantity of biodiversity is important.[162] Nature Iraq approach in their survey of the CSR in 2009 is presented, which covers bird and botanical diversity primarily but also to lesser extent wild life. They identified Key Biodiversity Areas (KBA) in KR. In which they identified patches (Hubs) that are of considerable size and support viable population that are distinct.

On this base some distinct spices locally and globally also a new observed spices in KR that recorded for first time in Iraq will be mentioned. 400 birds were recorded in which three endemic to the region and twenty of those are regularly occurring as "Globally threatened". According to Ararat , K. leader of Nature Iraq's KBA surveys in KR a flock of 410 *Lesser White-fronted Goose Anser erythropus* and significant records of *Eastern Imperial Eagle Aquila heliaca* – both at risk – are observed. The presence of some important carnivores "wolves, brown bear, wildcats, and leopards" were recorded in the KR.[163] Plate 4.3, Plate 4.4 and Plate 4.5 show the few sample (from Nature Iraq[164]) of spices including: recently recorded, typical spices, globally endangered and vulnerable spices.

[162] Kellert, S.R. & Bormann, F.H. (1991) *Ecology Economics Ethics: The Broken Circle*.
[163] Bird Life International, http://www.birdlife.org/datazone/speciesfactsheet.php?id=7947
[164] Ararat, K., Hassan, N.A. (NI), Rahman, S.A. (UofS), Nature Iraq & Iraqi Ministry of Environment (2009) *Key Biodiversity Survey of Kurdistan, Northern Iraq: Site Review - 2009 Survey,* http://www.natureiraq.org/site/en/.

Plate 4.3: New record for the Iraq bird list Grey-neckedBunting (Emberiza buchanani) (L), Western White Stork (Ciconia ciconia) (M), Conservation concern Slender-billed Gulls (Larus genei)(R)

Plate 4.4: Endangered Egyptian Vulture (Neophron percnopterus) (L), Globally near threatened Semi-collared Flycatcher (Ficedula semitorquata)(R)

Plate 4.5: Globally vulnerable Wild Goats (Capra aegagrus) at Parzan (L), A globally vulnerable Lesser Kestrel (Falco naumani) bred at De Lezha (L)

Source: Koresh Ararat, 2009.

4.1.2 Cultural Heritage Resource

The remote history of Mesopotamian provide a uniquely reach and significant legacy of the whole humankind civilization. Due to this richness the area is frequently entitled by "the cradle of civilization". CSR has at least 1,307[165] known archaeological sites. Most important sites are subjected to investigation.

[165]Kurdistan Regional Government, *About Kurdistan Region*, http://www.krg.org/articles/?lngnr=12&rnr=143&smap=03010600

4.1.2.1 Historical Sites

The historical sites are coming across a wide span of time starting from Ice Age to modern history. That is why the selective set is presented. During Ice Age (120,000–10,000 years before present (B.P.)) people refuge to cave settlements like Baradost, Aqra and Piera-Maqroon mountains. Also other manmade caves across CSR can be found with the nearby river valley. The earliest forms of hominid and Neanderthals are found in Shanidar Cave, belonging to 60-80,000 years ago, with discovered tools and artifacts. In which 35 bodies in 26 burials found in the cave related with funerary goods and human remains that presented the family relationship of that era. [166]

Within the early Holocene era (10,000 years B.P.), due to fluctuating "climate to moderately warm climate with Quercus forests and poacean vegetation was recorded, and the cavemen evolved to Neolithic culture and hence moved to settle in plain areas and built the oldest villages of the world, Zawi-Chemi and Jarmo with continuing temporarily living in the caves". [167] Carbonized kernels of wheat which date back to 6750 B.C. were found at the Jarmo site 43 km SW of the city of Sulaimaniyah, a village which may have been one of the birth places of human agriculture, thus civilization[168]. There are tens of historical sites such as Hazarmerd, Zarzi, Karim Shar, Palegawra and Matarrah which indicate the presence of the first human activities toward civilization.[169].

Coming to more near history with starting of civilization and more formal form of human settlements, is represented by Mound that can be detected all over the CSR. Also remaining from Ashurian, Sasanian, Median and Achaemenid Empire down to the Islamic civilization can be found in CSR, ten of sites and stone art can be found across the CSR like temple of Zeragustian in Derbandikhan City and Stone Arte in Qradagh, etc. To summarize this layer the map have been developed by author that shows spatial distribution of this valuable historical site, see Figure 4.9.

4.1.2.2 Man-made Cave

Earlier Hominids lived in the CSR for millennia. Moreover life in caves and shelters as key settlements prevailed for the Middle and Upper Paleolithic periods. As Man-made caves mentioned under the historical site also, but the important in term of hydrological concern is worth to consider as well.

Bavian (Khanis) in the vicinity of Atrush were built upon the first intake structure and aqueduct that transport water by gravity to the historical settlements of Nineveh (in the era of Assyrian king Sanherib). Similar manmade caves are discovered in Deralok valley. It is worth to mention that some of this cave used as restaurants in touristic areas like Anishke waterfall in Dohuk). Moreover, some contains sophisticated water circulation system and some are the out let of Karst aquifer "Bekhme" and "Pila Spi" like Zahlum. [170] There are a considerable number of these caves but, the most significant ones in term of hydrological significant and landscape value is highlighted, Table 4.1, illustrate the name descriptive state of the location. Also see Figure 4.3, that illustrate the spatial distribution the hydrological outlets and it is covered under historical site as well see Figure 4.9.

[166] Stevanovic, Z., Iurkiewicz, A. & Maran, A. (2009) *New Insights into Karst and Caves of Northwestern Zagros Northern Iraq*
[167] Al-Ameri, T. K., Jasim, S. Y. & Al-Khafaji, A. J. S. (2010) *Middle paleolithic to neolithic cultural history of North Iraq*, Abstract.
[168] Hughes, H.D. & Henson, E.R. (1967) Crop production.
[169] Harlan, J.R. (1975*) Crops and Man: American Society of Agronomy*. Vol. 4, No. 3.
[170] Stevanovic, Z., Iurkiewicz, A. & Maran, A. (2009) *New Insights into Karst and Caves of Northwestern Zagros Northern Iraq.*

Table 4.1: List of man-made cave in CSR

Source: Author, 2010.

Man-made Cave	Governorate	Location
Shanadar Cave	Erbil	Barzan area, Shkaf village.
Baston Cave	Erbil	Bradost Mt., between Rawanduz valley) and Dyana basin.
Betka Cave	Sulaimaniyah	Makok Mt., Saruchawa spring and village
Zalum •or Zalm	Sulaimaniyah	Iranian border, Zalum spring and Khurmal village.
Kuna Masi Cave	Sulaimaniyah	Small Zab catchment, Chwarta area
Kuna Ba Cave	Sulaimaniyah	Darbandikhan city, Gulan Mt., Bani Khelan spring catchment
Betas Cave	Dohuk	Zakho, the upper catchment of Khabour River, Chiai Spizah Mt.
Smaquli Krozh	Erbil	Gali valley, Bnabawagi and Awa Kurds Mts.
Awa Spi	Sulaimaniyah	Garmian area, Sagrma Mt., Sangaw, Darzila village

*Established from the list by Stevanovic, Z. et al.

4.1.2.3 Mound

Is technical term in archaeology, it is defined as a "deliberately constructed elevated earthen structure or earthwork", planned for a variety of prospective uses. [171]. In the CSR names like mound, artificial hill and Tell is used. Also their function and size are different; it is created for human occupation and settlements as abandonment of a geographical site see Plate 4.6. The CSR contains a large number of remaining of this mound. Among the most famous is the Erbil citadel, the oldest continuously inhabited settlement on artificial Mound in the world, which has been settled since 6,000 BC. Also Kirkuk citadel a distinguishable artificial mound dating to 3000 B.C.

Plate 4.6: Mound with deteriorated case at Soran (L), Erbil Citadel on top of artificial mound at Erbil city (R)

Source: http://shivanita.files.wordpress.com/

The archeological team in the University of Heidelberg used Automated Tell Detection on North Mesopotamian, by means of Satellite Remote Sensing. The classifier had detected a lot of settlement mound in the area, mostly located in Makhmur plain in Erbil, since it is anciently important routes

[171] Wikipedia, Mound, http://en.wikipedia.org/wiki/Mound.

directly linking major centers like Ashur, Arba-'ilu (modern Erbil) or Arrapkha (modern Kirkuk). [172] For the purpose of this study a map has been developed accordingly. See Figure 4.9 that shows the mound distribution in the CAR.

4.1.2.4 Karez

A subterranean aqueduct, known as karez in Kurdistan Region, is an important part of cultural heritage. The karez in KR could be associated with any past empire belonging to at least 800 BC. Karez are ancient water resource management infrastructure that are engineered "to collect groundwater and direct it, through a subsurface tunnel with a gradual slope, to surface canals that provide water to settlements and agricultural fields". Many infiltration karez gathers water from aquifers at the catchments formed due to hilly terrain. Some Karez extends for a number of kilometers through wide alluvial plains, and others run alongside stream valleys where they reach the shallow water tables nearby the streams. To guarantee long-term constant flow, karez are built in aquifers that are rechargeable at seasonal base. The water table is high with—2 m to 10 m deep from surface— and situated in areas of permeable rock to warrant steady recharge to the aquifer underneath. Karez in CSR have been mined "into porous, water-bearing beds of alluvium (26%), conglomerate (10%), and limestone (63%)". Most of these karez (84%) are in Sulaimaniyah governorate and 16% in other part of the CSR The decline of 70% Karez is recorded. The layer includes Infiltration karez (qanats), see Figure 4.9.[173]

Karez tunneis were mined in a range of profile shapes, including "rectangular, round-arch, and pointed-arch ceilings", see Plate 4.7. Several tunnels have a narrower water channel mined alongside the length of the tunnel ground for maintenance process (e.g. straddling water flow, maintaining lateral erosion of the main tunnel walls and etc.). The existing system belongs to different time span aging 350 to 90 years. So Karez is not only a sustainable infrastructure but also due to its unique engineering design, it becomes a part of cultural heritage resource.

Plate 4.7: Round arch karez tunnel in limestone at Zimzimuk (L); Pitched and pointed arch Sarsula karez at Girdashekhal (in limestone) (R)

Source: Dale Lightfoot, 2009.

[172] Menze, B. H., Muhl, S. & Sherratt, A. G. (____) *Virtual Survey on North Mesopotamian Tell Sites by Means of Satellite Remote Sensing*. http://hci.iwr.uni-heidelberg.de/publications/mip/techrep//menze_07_virtual.pdf

[173] Lightfoot, D. (2009) *Survey of Infiltration Karez in Northern Iraq: History and Current Status of Underground Aqueducts*:

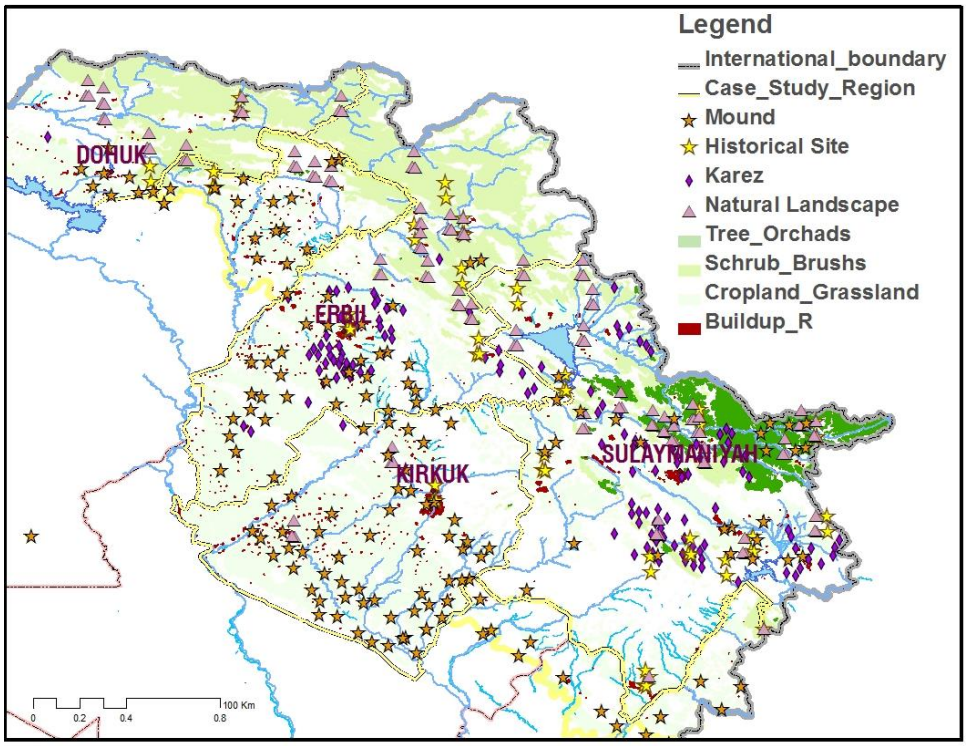


Figure 4.9: Cultural heritage resources in CSC.

Source: Author, 2010.

4.1.2.5 Climate Change Effect

The national condition has been derived from the recent research by related international organization. In order to make investigation, different modeled data is presented to illustrate the projected effects and highlight the recent climatic phenomena, as well as the potential impacts.

Depending on the climate change projections for the 2020s -in the Middle East (that are derived from simulation outcomes of four different global climate models for the IS92a emission scenario- no reduction in precipitation is projected. While temperatures increase for all the season are predicted, which mean temperature will rise significantly by (0.6-2.1 °C) in the North Region, with difference of 0.3 °C in a comparison to rest of Iraq. [174]

Beside the general trend of drier region, other region-specific models forecast rainfall increase in specific areas, including CSR. Other model predicted decrease in precipitation in CSR up to specific period and a diverse trend (increased trend) projected after that period. So accordingly while 20-30% drop in runoff projected in Iraq by 2050 at the same time increasing precipitation is predicted in CSR. [175]

The impact of climate change is there regardless of the differences forecasting models. The sand storm phenomenon is a new phenomenon in the CSR, the metrological station for all the cities in

[174] El-Fadel, M. & Bou-Zeid, E. (2001) *Climate Change and Water Resources in the Middle East: Vulnerability, Socio-Economic Impacts, and Adaptation*.
[175] Evans, J.P. (2008) *Changes in Water Vapor Transport and the Production of Precipitation in the Eastern Fertile Crescent as a Result of Global Warming*:

CSR are reporting the incremental trend in frequency and intensity. However the intensity is in lesser degree, but in June 7 2009, Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite recorded thick dust over the most part of CSR except for very north and E part.

Another impact of drought (together with demolishing of villages policy, drilling a large number of well in the urbanized area, development and sealing effects around the infiltration well) is drying up the Karez in CSR. This is due to loss of precipitation that has significantly decreased aquifer recharge and put the groundwater resource availability in CSR at risk. "Almost 40% of the karez in this region have died since drought in 2005 and another 70% of those that were still active have been lost since the onset of drought in 2006-2008." [176]

U.S. Department of Agriculture's Foreign Agricultural Service announced that the area most affected by drought is the CSR, "since it is the country's historical breadbasket, where rain-fed wheat is grown". [177] Also Inter-Agency Information and Analysis Unit (IAU) and United Nations Office for the Coordination of Humanitarian Affairs (OCHA) have estimated cropland affected by drought in two Consecutive years 2008 – 2009. They estimated the range between affected cropland/ total crop land, Erbil and Kirkuk governorate were listed as most affected area by 46%-56%, While Sulaimaniyah city with 4-5% and no effect recorded for Dohuk. [178]

IPCC was observed the amplified levels of drought during 1990 to 2002, in comparison to the baselines, two cycles of drought 2003, and 2007 consequently are recorded. Analysis of Vegetation condition determined by satellite-derived vegetation index (NDVI), support the growing environments enhanced because of better weather in the CSR after a drought cycle of2002. Seasonal NDVI improved all over the northern vegetation growing zone as compared to average conditions during the base years (1997/98- 2000/01),[179] see Figure 4.10.

The last cycle of drought in 2007/2008 which continued to 2009, had affected growing season. The growing condition of plant has observed by Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite from 07-04-2009 to 22-04-2009. The productivity level has been illustrated by color scheme: the brown zones show the below-average plant growth in comparison to baseline years (2000 and 2008); green zones demonstrate above-average growth; and tan colored zones illustrate average conditions, see Figure 4.10. [180]

[176] Lightfoot, D. (2009) *Survey of Infiltration Karez in Northern Iraq: History and Current Status of Underground Aqueducts*:
[177] NASA, Earth Observatory, *Natural Hazards, Drought in Iraq*, http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=38914
[178] Inter-Agency Information and Analysis Unit (IAU), Iraq, *Drought in Iraq*, http://www.iauiraq.org/documents/481/Newsletter-July09-v1.pdf,
[179] U. S. Department of Agriculture, Foreign Agricultural Service (FAS), *Iraq Crop Production,* http://www.fas.usda.gov/pecad2/highlights/2003/01/Iraq_update/index.htm
[180] http://www.fas.usda.gov/pecad2/highlights/2003/01/Iraq_update/index.htm

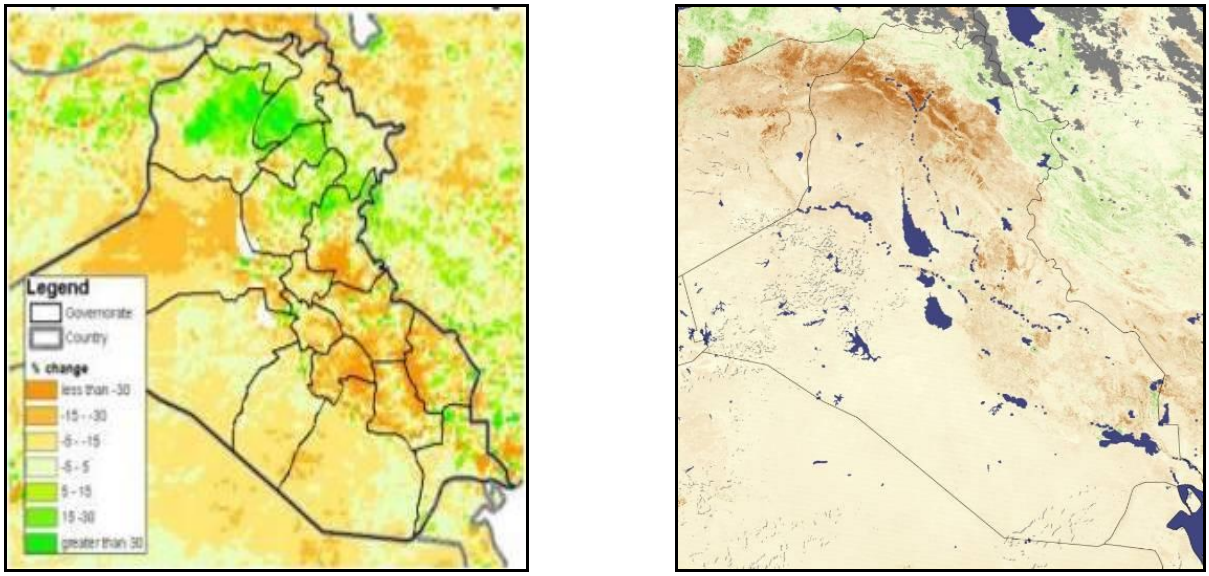


Figure 4.10: Comparison of 2002/03 seasonal NDVI to short term Average(L),Drought in Iraq (April 7-22, 2009), (R)

Source: PECADs Weather and Vegetation Index Monitoring Analysis Product, National Aeronautics and Space Administration (NASA).

Comparing both model the area (S and SW of CSR) that are having degree of NDVI increase it is ranging from +15% to+30% in 2003 Model, it has negative growing condition after the ending up drought effect in 2009 model. Another important difference is the N and NE belt of CSR degree of NDVI increase it is ranging from -15% to+15% in 2003 Model, while showing totally positive growing condition in 2009 model.

In the Middle East region, ecosystem damage and species loss are predicted to be substantial in mountainous regions where flora distribution is to alter to higher altitudes. Other impacts like probable reduction in GDP due to climate change on NDVI generally and particularly agriculture and a currently low adaptation capacity are also probable. [181] Most importantly is the impact on population, staff from the directorate of FAO water has reported to the UN agencies of the drought challenge to the population in Iraq.[182]

On the other extreme of drought is flood risk at the CSR, since the area has a variety of typographical feature and due to intensity of precipitation in wet season, there are some parts are highly vulnerable to flood like Erbil and Kirkuk Governorates.

[181] El-Fadel, M. & Bou-Zeid, E. (2001) *Climate Change and Water Resources in the Middle East: Vulnerability, Socio-Economic Impacts, and Adaptation*.

[182] OCHA, IAU, UNAMI & HDS (2009); *Iraq 2009 Drought Information Report #1*, http://www.iauiraq.org/reports/OCHA_Drought%20Report_no1.pdf

4.2 Scope of Case Study City

4.2.1 Natural Resource

4.2.1.1 Topography

Geographically Sulaimaniyah is located between 35° 40’ 06’’N to 35° 25’ 54’’N and 45° 14’ 48’’E to 45° 37’ 00’’E. Its average altitude is 850 m. The city sits on the north-eastern side of the Tanjero valley and just S of the Sarchnar/ Chaq-chaq rivers with mountains to the NE steeply rising to 1,500m ridge (Shak-I Dolamayan linked to a higher second ridge of 1,700m (Shak-I Haruta). The topography varies between plains, foothills and high mountains, with high variation in height, See Figure 4.11 that illustrate the topographic range in relation to existing city.

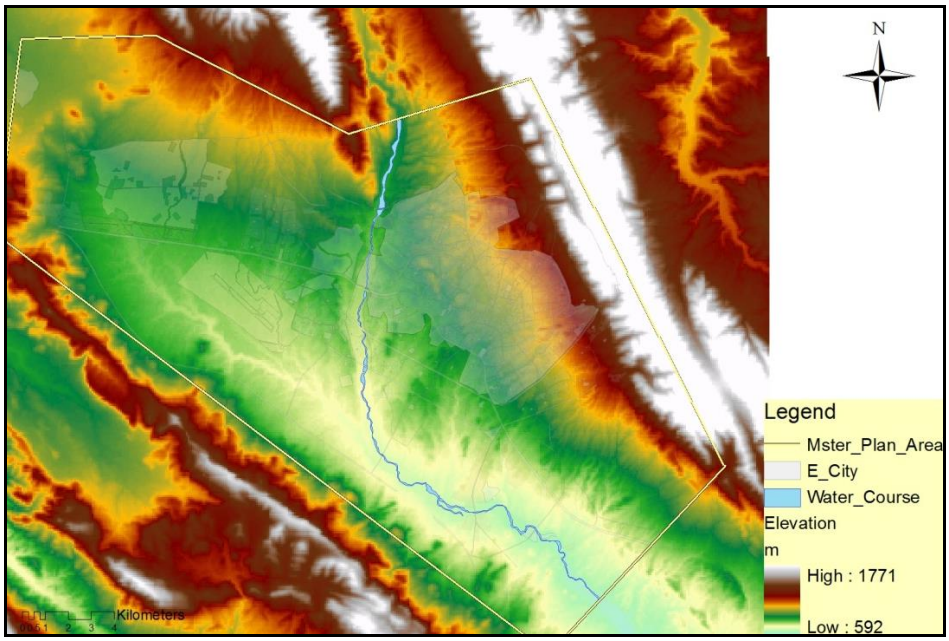


Figure 4.11: Topography map of the CSC

Source: Author, 2010 from Municipality of Sulaimani City data.

4.2.1.2 Geomorphologic Setting

Different Geomorphologic unit can be identified within the CSC, which is so important to understand the existing situation. The city surrounded by High folded zone of Zagros highlands. Azmer fold (1700m) and Goizha fold (1500m) extending from NE to NW direction with 15.83 km and 12.39 km respectively. Piramagroon fold in northW and Baranan fold in the S-SW. Also Chaq-chaq and Sulaimaniyah fault each extending 6km and 10 km from NW of the CSC. Beside the Zagros highlands there are the mountains hill sides that cover the area between the existing city and the folds extending from NE to NW side along the mountain chains, see Figure 4.11.

The existing CSC is mostly fall within the Recent Deposit that consists mainly of River Terraces Deposits, pediment deposits, Alluvial Fan Deposits, Flood Plain Deposits, see Plate 4.8. River terraces represent the second major Pleistocene deposit which covers both sides of Qiliasan and Tanjero River with (5-10 m) thickness. Alluvial deposits which form fans along foothills of Goizha,

Piramagroon and Baranan mountains around the CSC. Flood Plain Deposits can be found in Qiliasan and Tanjero Rivers grading from course gravels to fine silt and clay, with (10-15 m) in thickness. [183]

Plate 4.8: View of the city from Azmer Mountain shows pediment deposits areas (T), Views over the city of Sulaimaniyah from W to the mountains chain and hill side in the north BL and BR.

Source: Municipality of Sulaimani City, 2008.

4.2.1.3 Geology and Hydrogeology

According to new sequence stratigraphic classification the CSC is classified as the depositional part of High Folded zone. The tectonic formation, dating from Lower Cretaceous (Valanginian-Turonian) represented by Balambo Formation oldest formation in the area. Below this formation the sequence is represented by unknown Jurassic rocks; the youngest unit is represented by recent deposite of Quaternary (Pleistocene) which cover part of the studied area.[184]

The groundwater resource for Sulaimaniyah can be considered a region with good groundwater resources, with a number of permanent springs and Karez. The municipality reports there are 56 karez in the city, with 26 of them in use today, with different flow capacity (15 l/s to 1 l/s).[185] The underground waters are present in shallow depth of 3-50 m. [186] The CSC characterize by different aquifer system with different hydro-geological characteristics, starting from "Recent alluvium, Residual and older terraces, Lower and Upper Bakhtyari formations, Lower and Upper Fars, Kolosh to Pila Spi formations and Balambo to Tanjero" There are about 12 monitoring wells in Sulaimaniyah city within the Karstic-fissured aquifer system with perennial springs such as Sarchnar Spring. Also it characterized by Carbonate rock type that have a good capability in storing and retaining water, due to pores and crack texture that they have.

[183] Rozhan Faraidoon Abdulrahman, (2008).The Geographic Analysis of the Difference Ground Water Pollution in Sulaimania District.

[184] Zoran Stevanobic. Miroslav Markovic . Adrian Iufkiewicz, (2003). FAO Coordination for Northern Iraq , Hydrology of Northern Iraq. Climate ,Hydrology .Geomorphology of Northern of Iraq .Second Editin ,Erbil, Vol.1 .

[185] Coalition Provisional Authority (CPA), (2004). Master Plan and Design of Sewage Network and Treatment Plants for the Cities of Dahuk, Erbil and Sulaymaniyah: Sulaymaniyah Final Master Plan – Volume I of III Main Report.

[186] Ministry of Water and natural resources: Sulaimani Groundwater Office, 2008. Unpublished data.

4.2.1.4 Soil

However this is one of the basic layers, in landscape planning, but due to the unavailability of soil map of the CSC the author try to illustrate a descriptive overview to the CSC. In this concern it is of great necessity the development of comprehensive soil map for the city, so further research and study should be carried out. Concerning the suitability of plantation chemical, physical characteristics and soil texture are to be dealt with.

The main characteristics of Sulaimaniyah soils are the presence of soil horizons and the presence of moderate organic matter. The characteristics of these soils are the process of self mulching and homogenization or churning of the soil to a depth of up to 70 cm below the surface. Thus the surface material, which had filled up the cracks, will be mixed with soils from deeper horizons. This continuous homogenization processes have a favorable influence on soil structure, permeability increasing organic matter of the soil and fertilities.

Generally the city is covered by two distinguished soil classes, starting from the boundary of the existing build up area. The **Mountain Soil** zone is classified by broken and stony land. It covers the high slope mountains area of Azmer Mountain that surrounds the city from N and NE direction. "The soil depth is 10-30 cm grading to the lime accumulation layer"[187]. It consist soil types namely Vertisols, Entisols and Mollisols. However this category doesn't have soil salinity problem but rather has the erosion problem due to steepness degree and precipitation factor.

The plain and hill side soil zone is classified as Chestnut Soil of Bedmont. All the plain area is covered by this type. The soil depth varies between shallow and deep, with organic content is ranging from 1.5-4%. This category doesn't have nether salinity or erosion problem.

"The valleys are synclines, filled with gravel of Bakhtiari formation covered by several meters of fine textured soils. The clay content exceeds 35% in most cases. The soil texture ranges from sandy loam to clayey soils and the dominant soil texture classes were sitly, clay and clay. Also narrow strips of medium textured soils exist along Tanjero River. With no exception, all the study soils are calcareous. The lime content is usually above 20%. The active calcium carbonate makes up less than 50% of the total calcium carbonate." [188] In the upper part of Goizha Mountain, Limestone rocks laminated with heavy textured soils (silty clay soil) were observed; in this harsh ecosystem the wild Almond is found. [189]

4.2.1.5 Land Cover

This part is investigating the main land cover or the natural urban morphology surrounding the buildup area. One of the most dominant cover is the urban area but it is dealt with in next subsection.

[187] Abdulrahman, R.F. (2008) *The Geographic Analysis of the Difference Ground Water Pollution in Sulaimania District*. Master Thesis

[188] Jalal, J. (2008) *Natural Resources and Its Utilization for Agricultural Development in Sulaimany Governorate*. PhD. Thesis

[189] Karim, H., Abid, S. & Salh, B. (2009) *Green Spaces in Urban Area: Analysis Of Existing Urban Green Space in Suliamni City*. Master Thesis

- **Woodland**

The CSC falls under the **Mountain forest zone** according to main classification by Zohary and Chapman, it has also classified as a Mediterranean Forest Belt. Climatically CSC is suited for forest and grassy kind. The forest of low stocking density can be found in the mountains foot hills at the N and NE part, and in the S and W part of the city the grass and shrub can be found in the plain. See Figure 4.12 that illustrates the vegetation type according to different altitude and soil formation in the CSC with its surrounding area.

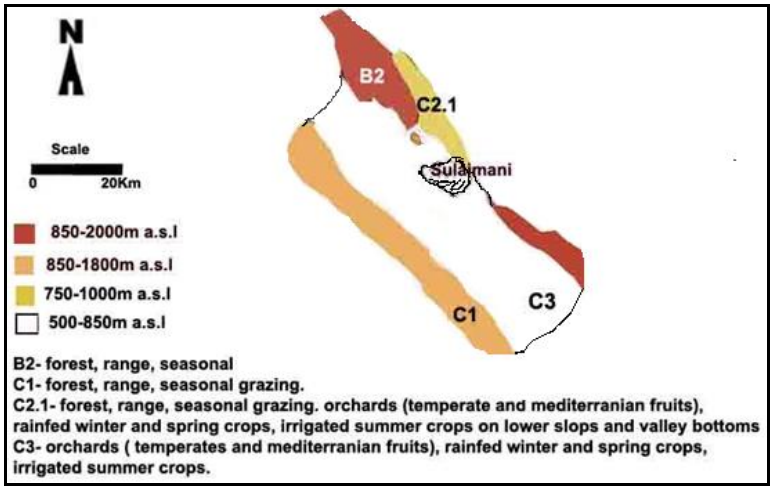


Figure 4.12: Natural vegetation covers of Sulaimaniyah City

Source: Modified after Berding, 2003.

All historically recorded natural forest is deforested, the upper portions of mountains are generally without any vegetative cover now, due to man's activity in accelerating the erosion force by overgrazing and exterminating the forest cover. Typically for the city the type of trees found are a indigenous type of oak, almonds, crataegus, malbary, juniper, Summaq and Muhalab. The wood cover consists of some pine forests on the mountains overlooking Sulaimaniyah. Also the riparian thin woody covers a loge side Qlyasan river, see Plate 4.9.

Plate 4.9: Riparian thin woody covers in W (L), New planted Pine forests in the North (M), Surrounding landscape (scrub bushes) (R), Natural vegetation (mostly grass) in the surrounding landscape in summer

Source: Municipality of Sulaimani City, 2008.

- **Open land**

The open land mainly consists of agricultural area that surrounded the city. The agricultural typologies consist of two main types. Irrigated area of agricultural land which rely upon untreated wastewater. Pasture or areas that sustain rain fed crops only like grain crops of barley, wheat and other rain fed cultivations. This typology covered the plain and categorized under C3 group, see Figure 4.12.

- **Surface water**

At the city level there is no considerable water body. There are two main rivers in the city: Qlyasan and Tanjero rivers. The river bed is filled in the rainy periods; its width is between 50m and 100m.Tanjero River represents a small river formed by linking of two major streams (Kani-Ban and Qlyasan) with other small tributaries, located S of CSC. Tanjero River starts from SW and flows to SE, before joining Darbandikhan Lake. Tanjero River catchment's area within Sulaimani City and it is elevated at (656-787m) above sea level. Qlyasan river (Chaq-chaq river) flows NW of the city. The Sarchnar spring is a tributary of the Tanjero, but much of the spring water is utilized for water supply in the city and for a tourism area. The flows in the Tanjero S of Sulaimaniyah comprise of raw sewerage and water supplied by karez.

There was an artificial reservoir (Sarchnar Reservoir) with reserve of 4.5-5 million m^3 capacity, with no plan to support irrigation for agricultural purposes but rather was acting as a flood protection reservoir to the western side of the city. Nevertheless the Dam has been collapsed due to flood in 2006.

There are no wetlands, except for areas directly adjoining the river, which relies on the greater part of its flow from untreated wastewater from the city, as well as to some karez.

Regarding the most important water source which is Renewable water resources, the rainfall water resources include only the internal renewable water resources. According to FAO the renewable water resource for Sulaimaniyah district is 1607.88 million m^3[190] .The recharge rate of underground water is estimated by 50% in Sulaimani basin.

4.2.1.6 Flora and Fauna

A biome of CSC consist of indigenous tree species and local indigenous non tree species, thus beside to non indigenous specie. The local indigenous tree spices are “Oak, Juniper, Pistachio, Maple, Willow, Plane, Poplar, Ash, Walnut, Pine, Tamarisk and Plum” [191] To have a comprehensive overview about indigenous tree species in CSC, see Appendix D.

“The terrestrial vegetation found in the area is human influenced. Human intervention will increase, as there is demand for new urban growth areas taking over agricultural land”[192]: Up to date there is no comprehensive updated research about the condition of biodiversity and its health in and outskirts of the CSC. It is worth to highlight that in the Tourism Master plan, by Canadian company BLUE FOX Geomatics Inc., they developed a plan that consists of three main zones in terms of

[190] Ministry of Water and Natural Resources KRG Iraq (2008) *Sulaimani Groundwater*.

[191] Nova,W. & Blue Fox Geomatics Inc.(2005). *Sulaimaniyah Urban Forestry.*

[192] CPA, (2004). Master Plan and Design of Sewage Network and Treatment Plants for the Cities of Dahuk, Erbil and Sulaymaniyah: Sulaymaniyah Final Master Plan – Volume I of III Main Report.

biodiversity namely 'High, Medium and Low intensity biodiversity zones'. This correspondingly represented in the distribution of land use and greening intensity.

4.2.2 Built Environment

4.2.2.1 Urban Structure

The city has continued to grow in an organic manner to the EW direction due to the natural restriction of the mountains chains and fertile agricultural land in the S. The historical centre is located in the eastern part centered around the Bazaar forming city center (CBD). The old city is characterized by very high dense structure. On the old city periphery older houses have been demolished to pave way for modern architecture with three to four storey buildings. The existing city old boundary was delineated by the city's 60m wide ring road with 7.52 km in EW direction and 5.52 km NS direction. [193] This was a physical boundary limiting development during the Saddam Hussein era up to 1995. This boundary has been overtaken by developments. The urban structure inside the 60m wide ring road is characterized by a high density, although outside this limit there are numerous developments but nevertheless the unfiled pattern with a lot of vacant and undeveloped land can be observed. See Figure 4.13 that illustrates the deferent historical development stage of the CSC.

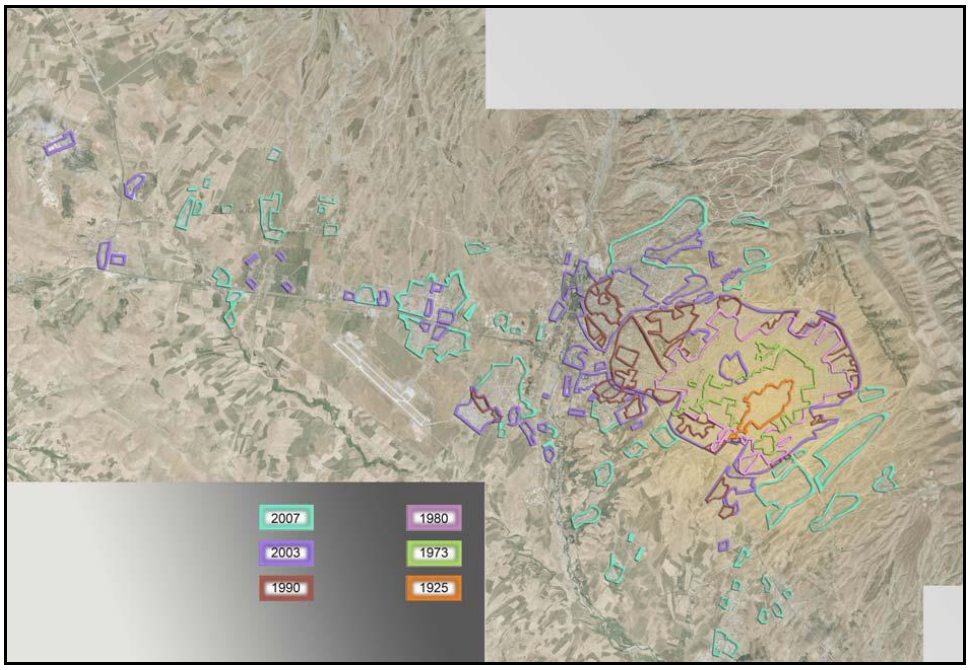


Figure 4.13: Sulaimani urban development in the year 2007 (2003, 1990, 1980, 1973 and 1925)

Source: Municipality of Sulaimani City- (IGCO), 2009.

To cope with the city's rapid development the city commissioned the German company IGCO to develop a master plan in 2007 with a planning period ending 2038. The plan was to make provisions for current and future land demand, physical extension of the city that orientated to N, W, S and E direction of the city and to fewer range to E and S tip.

[193] Ministry of Municipality and Tourism KRG Iraq, Municipality of Sulaimani. (2008) *Sulaimani Master Plan: Inception Report by IGCO*. Vol. 1.

4.2.2.2 Urban land Use

In any study concerning urban area, it is important to have a clear understanding to the existing land use. Residential use is forming the main urban morphology category. Housing Conditions is similar with no or few variety. The housing is rather dense and consists of individual two or three floor houses, terraced housing, or little apartment buildings rarely of more than four levels, all of them generally with flat reinforced roofs. The recently housing typology consists of a low portion of 'Housing Complex Project (Gated Community)' (with low rise building is mainly low density with single or semi-detached houses) and high portion of 'Self Produced Housing (Owner Built House)'. In this typology the plot size has been generally allocated plots of 200 m^2 by Government. The result is a fairly monotonous townscape of terraced housing, with very narrow-frontage houses and very little space, with only 2m setback without any soft pavements. Blocks of approx. 20 – 24 plots emerge to form a basic shape of settlement area. The special arrangement is repetitive for the most plots with slight difference in the area. This produces a very dense and compact structure with very poor vegetation percentage. It must be pointed out that some parts of the quarters inside the centre of the city are presently being rehabilitated, with the construction of more dense structure.

The city of Sulaimaniyah was founded relatively recently for Iraq, 250 years ago. So the heritage building is only belonging to this time period. Nevertheless "the southern part of the city contains sites of specific scientific, cultural or heritage significance due to the long history of human settlement in the region". [194] The planned land use as explained previously the last Master Plan has been finished late 2009 with the time span up to 2038. It is important to have an overview of the existing and planned land use so as to be integrated to the proposals of this thesis, see

Figure 4.14 .

[194] Ministry of Culture KRG Iraq (2007) *Booklet of Cultural Heritage Building in Sulaimani City*.

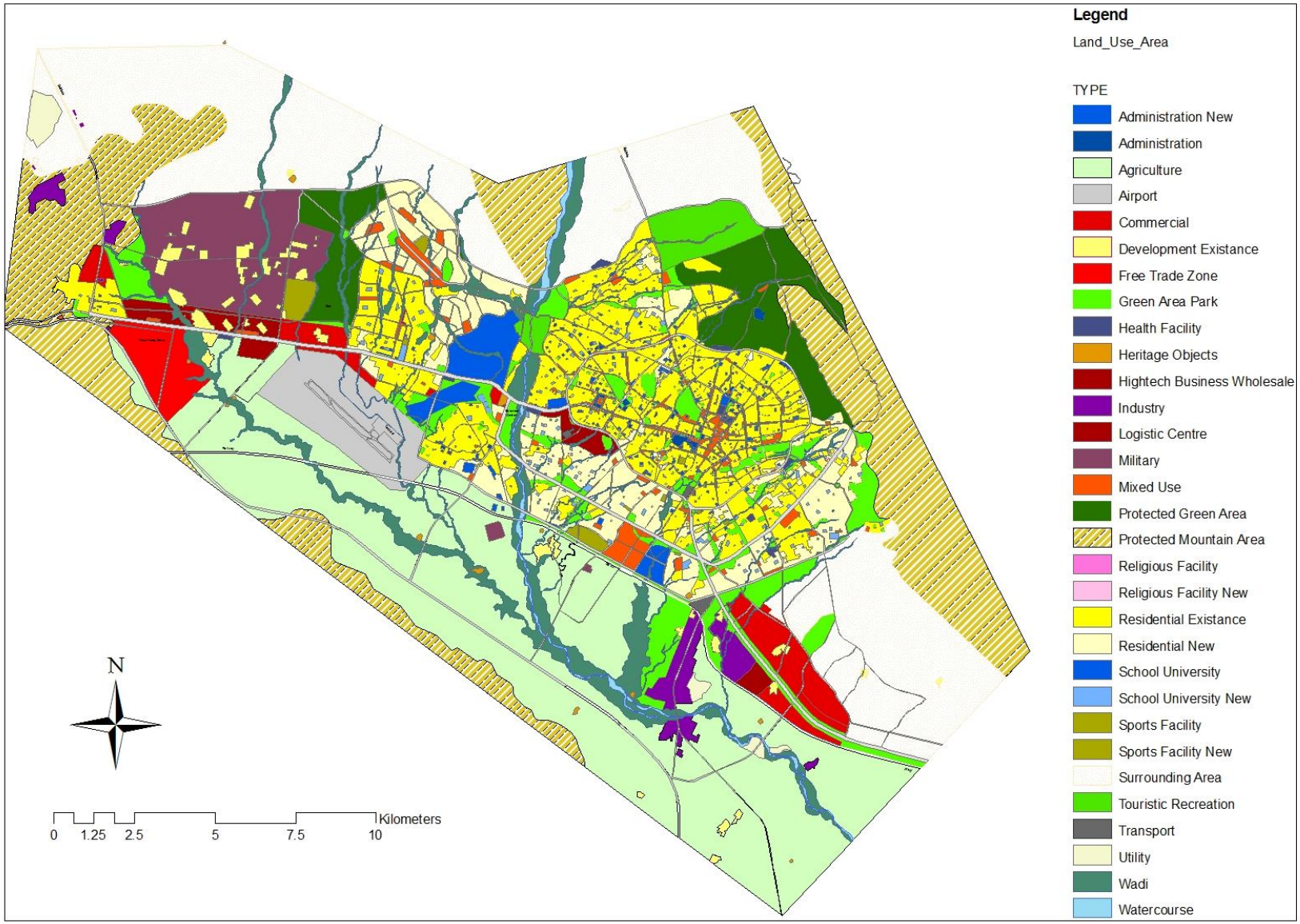


Figure 4.14: Existing and expected land use of Sulaimaniyah City

Source: Municipality of Sulaimani City, 2009.

4.2.2.3 Gray-Green Infrastructure

This part covers the existing Urban green areas in the CSC also related Gray infrastructure that strongly correlated to the development and feasibility of the GI plan at the city level.

- **Gray Infrastructure**

Domestic and irrigation water has traditionally been supplied by Sanharib water system (or karez), which consists of a sub-surface network of horizontal tunnels and galleries constructed to tap groundwater, or springs, in the upper limits of valley floor and eventually deliver it to desired lower level areas by gravity. Now the city receives treated water from either Dokan dam (60km W) or from Sarchnar spring on the N-western edge of the city. [195] This system was actively providing the demand up to 2005 to a considerable portion of the city.

Sulaimaniyah has an extensive wastewater collection system that takes raw sewage flows to the southern edge of the city and outfalls to a number of wadis before entering the Tanjero River. At the city level beside the health risk this lead to the contamination of soil, surface water and near underground water have been assured by many researches and studies.

- **Green Infrastructure**

  - **Existing Green Infrastructure**

The natural landscape of the CSC had been covered in Land cover part; in this part only the urban green areas are investigated.

Urban open space in the CSC is generally consists of parks, allotments, cemeteries, areas for sports and recreation. In terms of GI typology, the existing GI in the buildup area consist of, some parks or green areas, some small hills and street trees, contribute to enliven the urban landscape and provide convenient points of reference.

Sixteen hills exist inside and outside the ring road. This varies in height with the highest part 40m being in the NW part of the Sherwana quarter. On the adjoining quarters Zargata, Bakhan and Andazyaran further two small elevations are present of approx. 20 m. partly these hills are covered with vegetation and forest though other urban land-uses exist as well, see Plate 4.10. [196]

Major roads and selected neighborhood access roads are furnished with street trees. The municipality of Sulaimaniyah is responsible for panting and watering around 50000 trees only inside the ring road. Mostly the trees are planted in the street islands with single line and extensive lawn covering the rest part.

[195] CPA, (2004). Master Plan and Design of Sewage Network and Treatment Plants for the Cities of Dahuk, Erbil and Sulaymaniyah: Sulaymaniyah Final Master Plan – Volume I of III Main Report.

[196] Ministry of Municipality and Tourism KRG Iraq, Municipality of Sulaimani. (2008) *Sulaimani Master Plan: Inception Report by IGCO*. Vol. 1.

Plate 4.10: View from Bakham hill in north direction towards various hills of the city (T), Azadi Park (BL), Neighborhood park (BR)

Source: Municipality of Sulaimaniyah City.

Considering the quantity of GI or the urban green more specifically, there are different figures from different source. The previous Meyer of Municipality of Sulaimaniyah to News-Matiqe interview estimated total green area by 3% in the existing City. The current master plan by IGCO estimates green areas and forests as 1.72% of 51,926 km^2 (see Appendix F – Figure F.1).Together including the planned part the city area will contains around 5.48 % of green areas/open spaces.

Also the average share of inhabitants per existing green space area has been calculated as 3.8 m^2 per capita and with greening the planned urban green areas it will raise to 8.65 m^2 per capita.[197]

- **Planned Green Infrastructure**

The CSC is investigated correspondingly to the new Sulaimani Master plan and to the Tourism Master plan. According to the Sulaimani Master Plan, green concept basically represents the protection policy of existing landscape and urban green areas in addition to introducing new greeneries with new development and green area in N and E part of the CSC. Also it emphasized on the Wadis as an important typology especially along the Qlyasan River and the other large wadis since the vegetation provides a cool, pleasant climate, (see Figure 4.15)

Regarding the quantity of green/ open space had been estimated for the city within 100m ring road, by 5.48 % This includes public green space, open space and cemeteries. By the implementation of plan it will be raised up to 10.5% for the greater urban area, including areas of new development, with setting the target as 15 % of green spaces. [198]

In Tourism Masterplan those proposals laid down, spatially are mainly concerned with Sarchnar Area, Chaq-chaq, Azmer Area and Goizha Area. It is enclosing the city at N and W part of the city,

[197] Karim, H., Abid, S. & Salh, B. (2009) *Green Spaces in Urban Area: Analysis Of Existing Urban Green Space in Suliamni City*. Master Thesis
[198] Townsend, C.C., & Guest, E. (1974) *Flora of Iraq*. Vol. 3.

partly making use of existing touristic establishments (Sarchnar Area) and introducing new developments (Goizha Area). The plan introduced a sky train, including an accompanying maintenance road, all along the "tourist belt", and at the top of the mountains. The idea of utilizing the prevailing winds in the mountains via the introduction of a wind park is introduced (see Appendix F – Figure F.2).

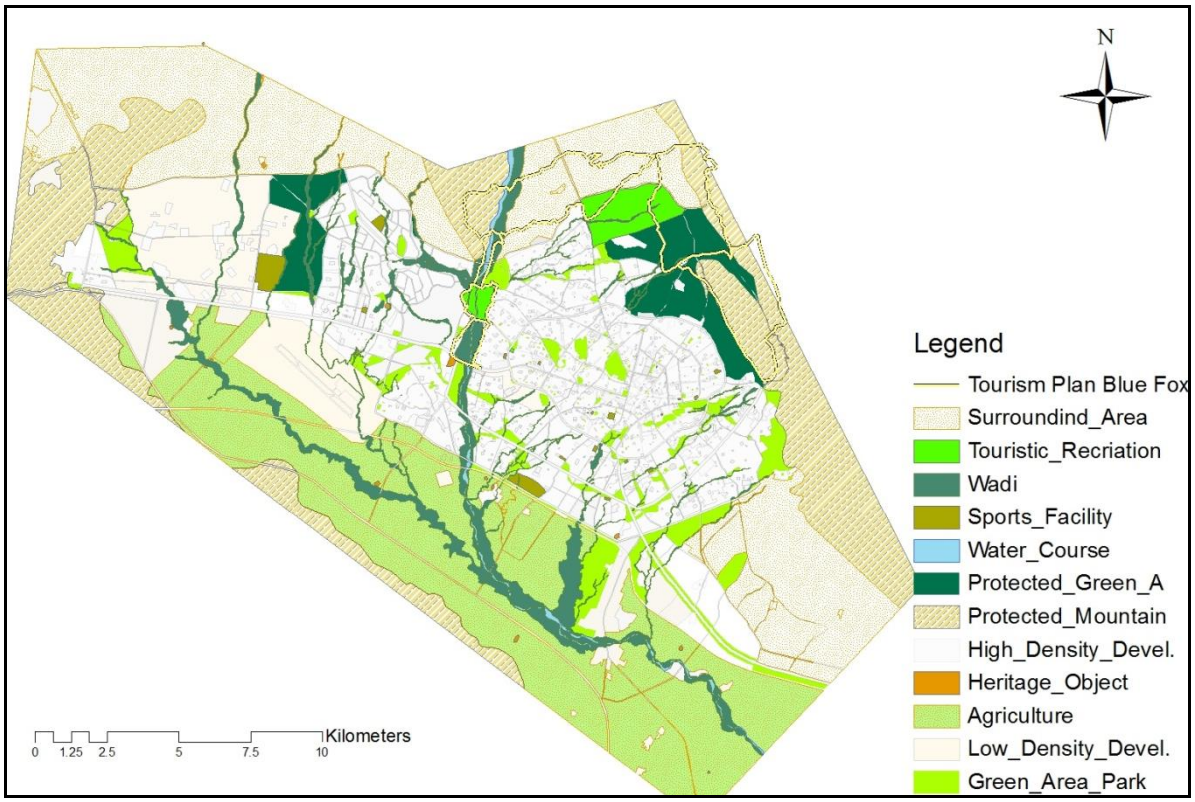


Figure 4.15: Existing and expected green concept in CSC

Source: Author, 2010, from Municipality of Sulaymani City data.

4.2.2.4 Local Climate in the City

Air-hygienic and meteorological investigations can deliver important support to solutions of planning problems[199]. According to the Koeppen classification scheme, climate of Sulaimaniyah city, is classified as interior Mediterranean, mild to cold winter, dry and hot summer[200]. This section sheds light into the local climate of the city with a 10 year interval from 2000 to 2009, based on unpublished metrological data (from Ministry of Transportation and Communication, Sulaimanya Meteorology Station, Ministry of Agriculture, General Directorate of agriculture Sulaimanya Agro-meteorological department, 2010). Temperature, precipitation and wind is highlighted while, for other climatic characteristic see Appendix G.

- **Temperature**

[199] Ministry of Economy Baden-Württemberg in cooperation with Environmental Protection Department of Stuttgart. (2008). Climate Booklet for Urban Development Online

[200] Critchfield, H.J. (1974) *General Climatology*. 3rd Ed. Pg 86.

Temperature is a very important factor which influences the humidity, evaporation, evapotranspiration, photosynthesis, vapor pressure and soil temperature. The temperature of CSC is characterized by low temperature during the winter of 4-10 °C and very high temperature 22-32 °C mean monthly. The average maximum monthly temperature is 39.4 °C in July, while average minimum monthly temperature is 2.25 °C in January, see Figure 4.16.

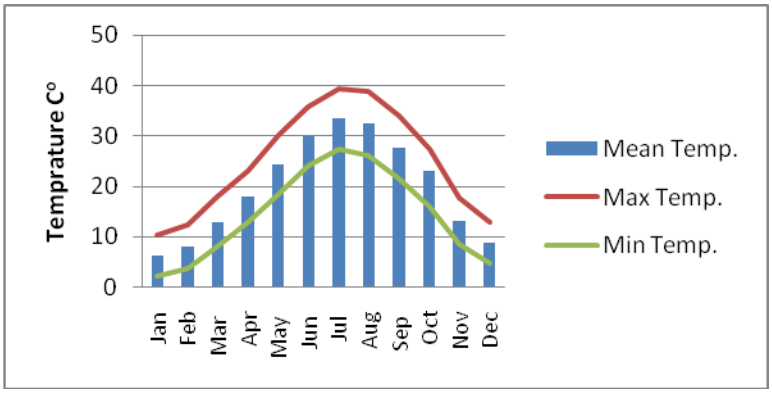


Figure 4.16: Average monthly temperature (2000-2009)

Source: Author, 2010.

➢ **Precipitation**

The local climate is characterized by wet season in winter and spring and a dry hot weather in the summer associated with high evapotranspiration from May to September. The average annual precipitations were 602.1 mm, with a maximum monthly precipitation of 112.15 mm in February. See Figure 4.17 the Ombrothermic diagram that shows the deficit and storage period of renewable water resource (rainfall).

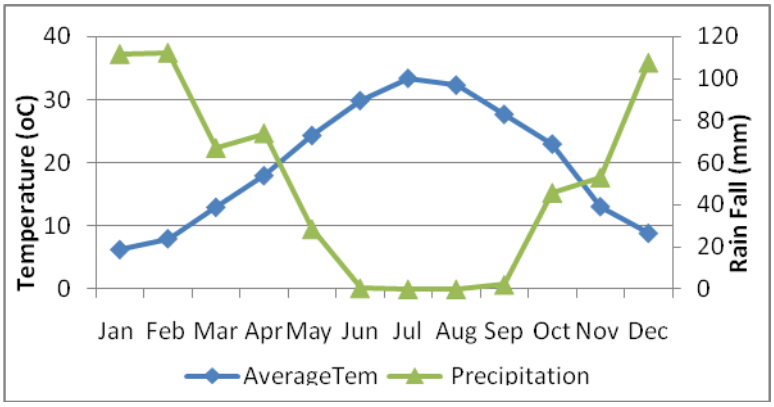


Figure 4.17: Ombrothermic diagram of CSC (2000-2009)

Source: Author, 2010.

➢ **Wind Speed and Direction**

The CSC like the CSR is under the influence of macro wind (global) and local wind effects. At the macro level it is under the effect of the Westerlies and the Polar wind in North direction. While the local wind that cause due to air pressure difference in topography can be categorized as Mountain and valley wind, Rasha-Ba. Mountain and valley wind, occur in summer season due to ambient air

temperature difference in two different direction from valley to the mountain in day time and vice versa cold air from the mountain to valley at night time. Rasha-Ba is the local name for a strong wind with high speed from the mountains to valley direction that occurs frequently in the CSC in winter and summer due to air pressure and differences in topography. Mean wind speed is 1.7 m/s the seasonal mean wind speed for spring, summer, autumn and winter are 1.8, 2.3, 1.5 and 1.4 m/s respectively. The direction their frequency of each season is shown in the Figure 4.18[201].

Monthly wind data from October to January showing the most prevailing wind direction from NE then SE and S direction while in February and March it is from S and NE direction. In April it is from SE, S and SW respectively. From May to September most prevailing wind direction is from SW and W direction except for July in which it is from NE and W direction.

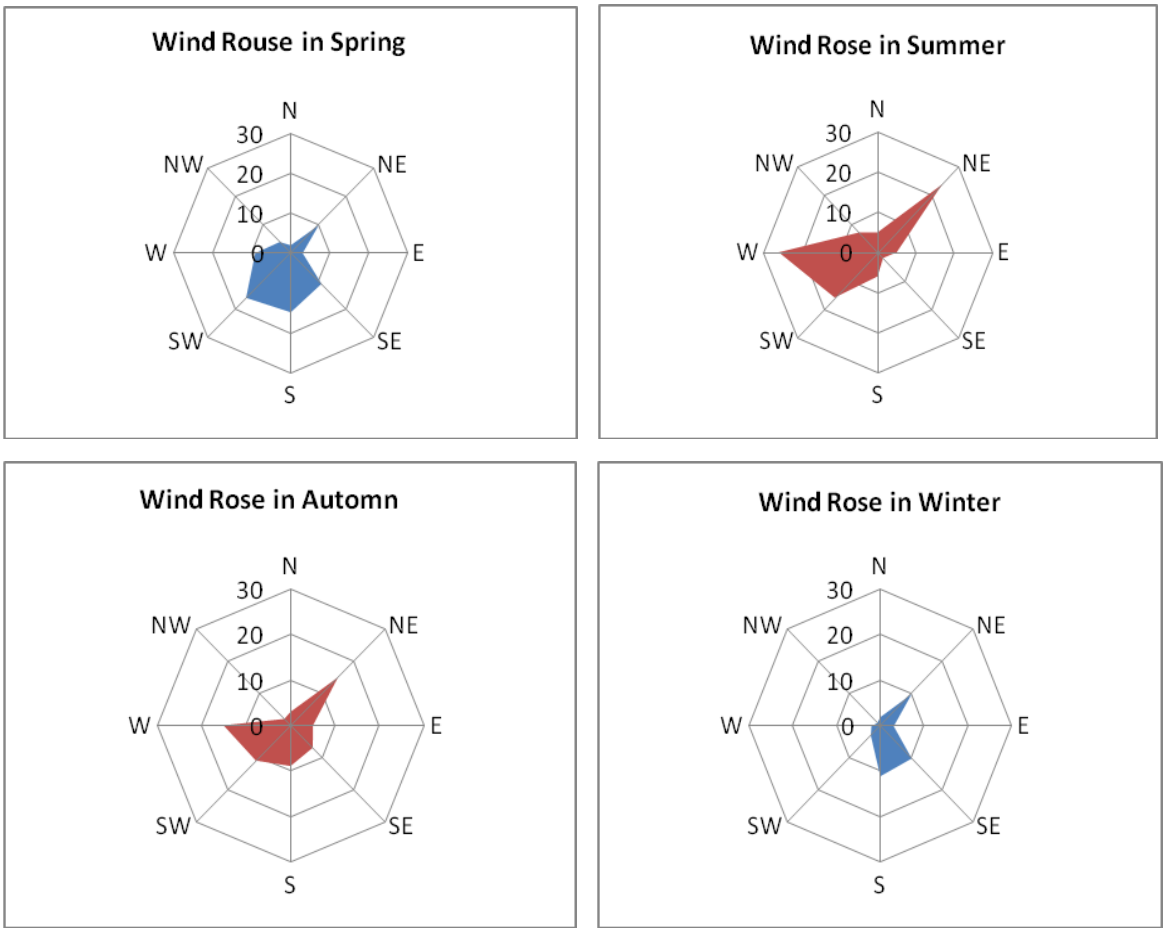


Figure 4.18: Wind Rose for CSC

Source: Author, 2010.

4.2.2.5 Effect of Climate Change

The Climate change projections for the 2020s, predict no reduction in precipitation. While predicted the temperature increase for all the seasons, Mean temperature will rise significantly by (0.6-2.1 °C)

[201] Ahmad, S.H.A. (2008) *Geographic analysis of the wind characteristic in the Iraqi Kurdistan Region and its Potential Exploitation*. Master Thesis

in the North Region.[202] In a research by Jalal, J. (by using Holt-winter method) the forecast for the future indicates presences of no drought in Sulaimaniyah regions with an average rainfall of 658 mm and 719 mm respectively, see Appendix G. To build a clear understanding of climate change and urbanization effect in the CSC that have a direct relation to climate engineering of the city, this section is adopting both the informative and analytical method.

- **Increasing Temperature**

The atmospheric climatic feature of a city is regulated essentially by the thermal and air-hygienic components of the bioclimatic influence complex. [203] In hot season, the region falls under the impact of Mediterranean anticyclones and subtropical high pressure belts passing from the W, SW to N. Southerly wind gusts over the Arabian Peninsula creating dust storms, increasing daily temperature to more than 45° C. [204]

To shed light on Local climatic behavior, the author depended on the analysis of the recorded data in the CSC. Increasing trend in both maximum recorded temperatures for each year since 1974 to 2010 can be observed. Figure 4.19 illustrates the historical incremental trend of maximum recorded temperature for 36 years with minimum temperature for the same day. The maximum temperature recorded in 1974 were 38.3 C0 while reached 45.3 C0 on July 31, 2008, with an increase of 7 C0 for recorded hottest day in a year within 36 year time period.

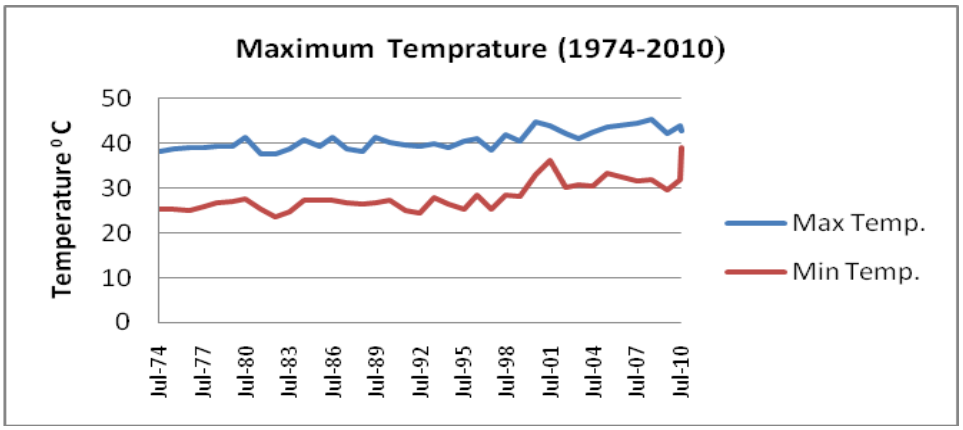


Figure 4.19: Historical trend of maximum temperature for 1974-2010

Source: Author, 2010.

The annual average temperature shift between the urban area and their surrounding landscapes are estimated as 1 to 2 °C. Mainly large temperature differentials (temperature lag rise on cloudless nights during the minimum daily temperature.[205] Urban heat island is also an important dimension to be dealt with. A comparison has been made between the climatic condition of the CSC and a nearby former village outskirts (Bakrajo). The difference of mean maximum annual temperature ranging

[202] El-Fadel, M. & Bou-Zeid, E. (2001) *Climate Change and Water Resources in the Middle East: Vulnerability, Socio-Economic Impacts, and Adaptation*.
[203] Ministry of Economy Baden-Württemberg in cooperation with Environmental Protection Department of Stuttgart. (2008). Climate Booklet for Urban Development Online .
[204] Ahmad, S.H.A. (2008) *Geographic analysis of the wind characteristic in the Iraqi Kurdistan Region and its Potential Exploitation*. Master Thesis.
[205] Ministry of Economy Baden-Württemberg in cooperation with Environmental Protection Department of Stuttgart. (2008). Climate Booklet for Urban Development Online.

betwee1.3 to 2 o C is recorded. With the annual mean humidity of 47% of CSC and 40.3% for Bakrajo with ad difference of 0.3 m/s less wind for the CSC. [206]

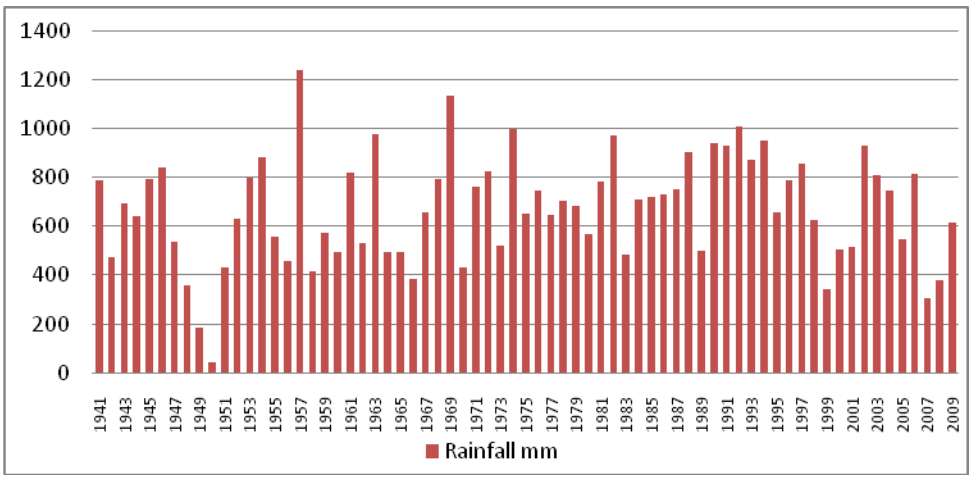
The different climatic patterns have been classified in the region as metropolitan, outskirt, villages and mountainous climatic patterns. The study recorded the exceeds of mean annual temperature of the metropolitan area by 1.22 °C, 2.1 °C and 3.91 °C to the other areas correspondingly. The degree of urban heat island is more in winter than summer and more in night than day. [207]

- **Flood Risk**

Since there is no data supporting incremental trend in Precipitation, but rather the stable or diverse trend is emphasized that is why this section will be dealt with in the local technical and natural climatic context. Local climatic effect that increase the flood risks can be analyzed due to certain factors, first the historical climatic condition in terms of annual fluctuation of precipitation rate, secondly the effect of different geomorphologic characteristics of the city, urbanization factors and technical constrains in the CSC.

- **Climatic Factor**

In order to have a clear over view, the overall average annual precipitation of Sulaimaniyah center during the period extending from 1941-2009 seasons (68 years), was found to be 671.097 mm. Depending on the agro-factor renewable water sufficiency, "a drought year or dry season can be defined by the amount of annual precipitation that receives 500 mm and less, and between 500- 700 mm is defined as a semi-dry season." [208] The amount of annual precipitation in the CSC follows a unique pattern of duration cycles. These cycles suggest drought seasons occurring every 7-8 years. Thus a drought season is lasting 1-3 years then followed by moist seasons again as indicated by Figure 4.20 in Sulaimaniyah. Precipitation rate more than 900mm that indicate occurrence of flood events in whole CSC, and with less than that rate flood event is recorded at certain part of the city (vulnerable areas and neighborhoods). As illustrated in Figure 4.20 the flood event recorded in the years 1957, 1963, 1969, 1974, 1982, 1988, 1991, 1992, 1994, 2002 and 2006 in the CSC.



*Ministry of transportation and Communication, Sulaimanya Meteorology Station, 2010.

Figure 4.20: Historical trend of rainfall in CSC (1941-2009)

Source: Author, 2010.

[206:] Abdulrahman, R.F. (2008) *The Geographic Analysis of the Difference Ground Water Pollution in Sulaimania District*. Master Thesis

[207] Sharif, A. (1998) *Erbil Area Climate, Comparative Study on local Climate*.

[208] Jalal, J. (2008) *Natural Resources and Its Utilization for Agricultural Development in Sulaimany Governorate*. PhD. Thesis

- **Geomorphologic Factor**

The record of precipitation rate shows variation in different area in CSC. Some time the difference reached around 14 mm, For instance in march 18 2007 the recorded precipitation in Sulaimaniyah climatology (884.8) center was 3mm while in another station in NE part was 16,25 mm. [209]

This different in precipitation rate in the high land in the N of the city will lead to the high rate of flow and accumulation of surface water at the low land in S of the city. This effect in particular will lead to flood vulnerability in certain neighborhoods like Zargate, Kostay-Cham and Sarshqam. Moreover, some of the neighborhood in the buildup area are located in the natural flow path of small seasonal rivers and valise like Malkandi and Shrawani, which are vulnerable to flood in wet season as well. [210]

- **Urbanization Factors**

The effect of urbanization on climatic engineering is of major importance. Effect of urbanization can be summarized in three main focal effects that are important for this investigation. The increase of surface runoff due to soil capping effect, as it has been described in the existing land use the existing city, particularly the area inside 60m ring roads is almost caped by impervious surface. This together with Geomorphologic setting and urbanization pattern is increasing the amount of surface runoff and cause flood risk in the CSC.

At a private scale of residential units the plot area ratio is too high. In regular plot of 200 m^2 only 20 m^2 is required by building code to be open which is only 10% of the total lot area. This ratio is dramatically in decreasing trend, due to the plot size and shape in a comparison to previous ratio that in some residential area before 1991 were varying between 25-45% of the total plot area.

The problem of surface sealing in that dense pattern is not only related to flood risk and its management, but also it plays a very important role in ground water recharge capacity in the area. The CSC with is surrounding area is known by Sulaimaniyah Sub-basin outcrops that cover “an area of 152.6 km^2, which is about 36.5% of the whole sub-basin of Sirwan river, and Darbandikhan lake. Structural and morphological settings create good conditions for a high rate of infiltration (see Appendix F – Figure F.3). Stevanovic and Iurkiewicz estimated the rate of infiltration to be more than 50% of total rainfall.” [211]

- **Technical Factors**

This resulted due to the natural topographic setting of the CSC in a combination to technical and planning problem. A greater flood problem is posed by the surface water runoff coming from the mountains close to the city on the NE, whose natural course is to flow through the city. There are box culverts along the alignment of the natural wadi water course through the city, which also received sewerage. However, these culverts, known colloquially as “box sewers”, appear to be undersized according to verbal reports, as flooding incidents though reduced still occur.

In some areas of the city, especially roads, the box sewers do not efficiently collect all local surface runoff. Due to the embankment level of the “60m ring road”, which can act as a dam and so cause

[209] Fouad, M. (2005) *The Effect of Land Topography on the Temperature and Precipitation of Sulaimaniyah City and Its Surrounding Mountains*. Master Thesis

[210] Jamal, S. (2000) *The Analysis of Urban Land Use Within Master Plan to Identify Urban Development Direction in Sulaimaniyah City*.

[211] Ali, S.S. (2007) *Geology and Hydrogeology of Sharazoor - Piramagroon Basin in Sulaimani Area, Northeastern Iraq*. PhD thesis

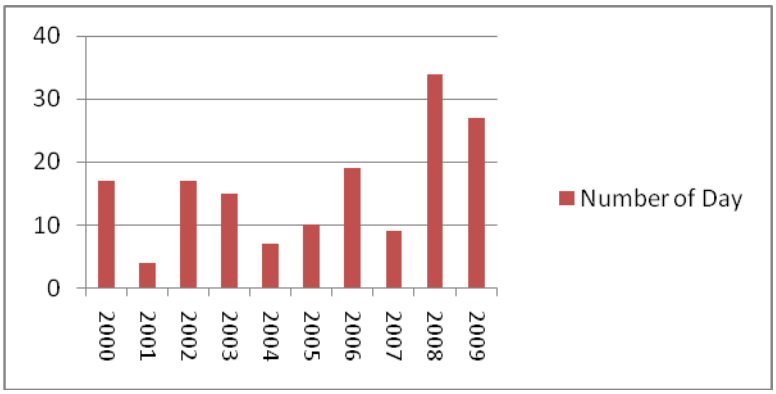
flooding, the free passage of water through such structures is limited. Also in localized parts of the city the box sewers are too high in relation to sewer pipes. During times of storms the sewer pipe back up with rainwater and flood some premises.[212]

4.2.2.6 Air Quality

Air quality defines the concentration level of air contaminants in the air that can pose serious effect on human health if concentrations become elevated. Pollutant concentration degree are affected by aspects as emissions sources, climatic conditions and topography.

Air Quality is strongly interrelated with weather conditions such as Wind, Inversion, Topography and Clear, Cloudless skies. While wind speed has impacts in diluting pollutants, but inversion and cloudless skies can increase pollution rate (e.g. producing high levels of ground-level ozone) and topography and complex altitude variance can cause trapping of pollutants. [213]

The climatic condition of the city is falling under the influence of national and intra-regional influence. In this regard the dust storm phenomenon that has a very influential effect on the air quality and living condition in the CSC is in incremental trend in intensity and frequency, see Figure 4.21.



*Ministry of transportation and Communication, Sulaimanya Meteorology Station, 2010.

Figure 4.21: Frequency of dust contention in CSC

Source: Author, 2010.

Due to the geomorphologic and climatic setting of the CSC, phenomenon of summer smog is identified. Poor air exchanges connected with strong sunshine, and vehicular traffic with its exhaust gases (e.g. NOx, and CO) is a main cause for smog that occur due to chemical alteration of the gases in the atmosphere cause the development of photo-oxidants. The most significant compounds here contain 'ozone (O3) and peroxiacetylnitrate next to peroxides, aldehydes, etc.'. [214]

[212] CPA, (2004). Master Plan and Design of Sewage Network and Treatment Plants for the Cities of Dahuk, Erbil and Sulaymaniyah: Sulaymaniyah Final Master Plan .

[213] Environment Canada, *Air, Air Quality Health Index, Air Quality and Weather,* http://www.ec.gc.ca/cas-aqhi/default.asp?lang=En&n=F3AF73F4-1

[214] Ministry of Economy Baden-Württemberg in cooperation with Environmental Protection Department of Stuttgart. (2008). Climate Booklet for Urban Development Online.

In the CSC, there are no stations neither mobile nor fixed one for monitoring air quality. Due to high rate of respiratory illness which is estimated as "6.5%for CSC in a comparison to 6.4% for Iraq"[215] and certain local phenomenon like inversion and smog, the city's climate is classified under a poor condition. For the purpose of this investigation the author will focus on the most related and major significant source of air pollutants, which is vehicular emission source.

The growth in individual motorized traffic (IMT), is connected with a substantial burden on the environment, especially through noise and air pollution[216]. This trend is also in incremental trend in CSC; see Appendix H – Figure H.1. The model split of the CSC is showing the 75.4% of vehicular mode (with 48.7% of individual vehicle) and only 14.6% for pedestrian mode. This can be regarded as a high share of vehicular mode if compared to the size and compatibility of the CSC. Consequently this lead to high traffic load at city centre (CBD), and CSC in general, see Appendix H – Figure H.2.

[215] (WFP) (2008) *Comprehensive food security and vulnerability analysis in Iraq: The 2008 Revision,* http://home.wfp.org/stellent/groups/public/documents/ena/wfp192521.pdf

[216] Ministry of Economy Baden-Württemberg in cooperation with Environmental Protection Department of Stuttgart. (2008). Climate Booklet for Urban Development Online.

5 Green Infrastructure Planning at Regional Level

This chapter includes the main vision of the GI Plan in order to direct the reader smoothly to the core analysis part, the logic behind choosing certain ecosystem services and then the developing of plan. It covers the baseline for evaluating and analyzing the selective information and data that have been presented for the CSR. The author sets a priority of the degree of importance of main constituents on the base of the possible and main issue that can be addressed at the regional scale according to GIP concept. In this concern, there is not a rigid model that agreed upon globally to be adopted by author, but nevertheless adopting GIP principal and adjusting and applying it in a way that best fits the local situation, is shaping the investigation. Then under the light of literature review and depending on ArcGIS9.3 software as a planning tool, the chapter presents step by step of developing GI Plan.

5.1 Plan overview

Strategic environmental capital, both natural resource and cultural resources makes up the fundaments for investigating, analyzing and developing the GI plan at the regional level. Since prescriptive details are not expected at this level, but furthermore, setting the priority importance of the specific environmental capital is of major concern. This shaped the starting point for developing the GI plan at regional level. On the base of CSR context and national context (Iraq), the main resources that have to be studied have been identified accordingly. Water resource and habitat and living environment identified as the most significant natural resources to be dealt with in this historical stage under the natural and manmade influence. While concerning cultural resources natural landscape, cultural heritage and historical site have been identified to be covered in the course of developing the GI plan.

The proposed GI Plan for CSR aims to identify and safeguard valued natural and cultural resources. Also aim to bring together the region's most important biodiversity areas, historical sites, and natural landscape including natural systems such as streams, Karez, watersheds, scenic landscape, and recreational site and to lesser extent working landscapes.

5.2 Analysis of CSR

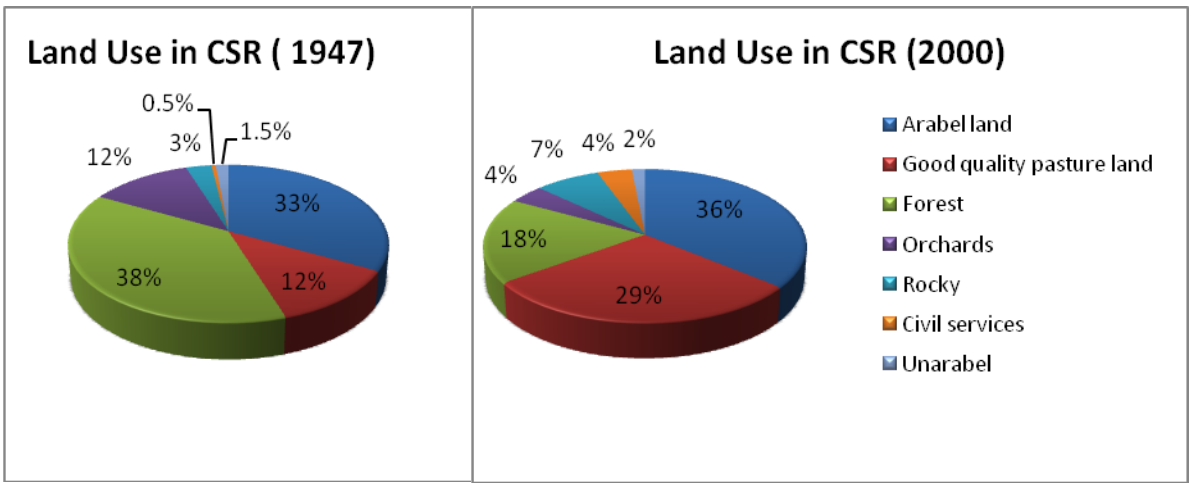
5.2.1 Natural recourse

5.2.1.1 Ecosystem Area

Human overexploitation of the natural forests, as well as shifting agriculture, forest fires and uncontrolled grazing, have denuded large areas of the natural forest. According to Chapman in 1957, the forest covered 60% of the mountainous region, decreasing to only 18% in 2009; whereas Earth Trend stated that the original forest area covered 13% of Iraqi land cover, but decreased dramatically to 2% of the total area.

Recently, the rate of deforestation by Annual Change in Forest is estimated by 0.20%. The forest zone was subject to various degrees of degradation. The forest density ranges from a completely destroyed (treeless) to that of good density. It is important to mention that most forest vegetation in watersheds does not provide proper protection against water erosion and water loss. The natural forest is not only the natural resource that has been damaged, but also the forest and agricultural

sector were damaged dramatically due to several reasons. EPA estimated that the percentage of 'Agricultural Lands Experiencing Greenness Declines' from 1980 to 2003 as 22.59%. Thus, due to the dependent of economy on Oil revenue, the political situation of the country, the shift of interest by local people, development on and around most ferial land on the plains, over grazing and the drought cycle that grip Iraq, including CSR, frequently, overall, the natural and managed land cover of the CSR have been shifted dramatically. This was due to natural and manmade reasons. See Figure 5.1 illustrating the land cover shift within half of the century.

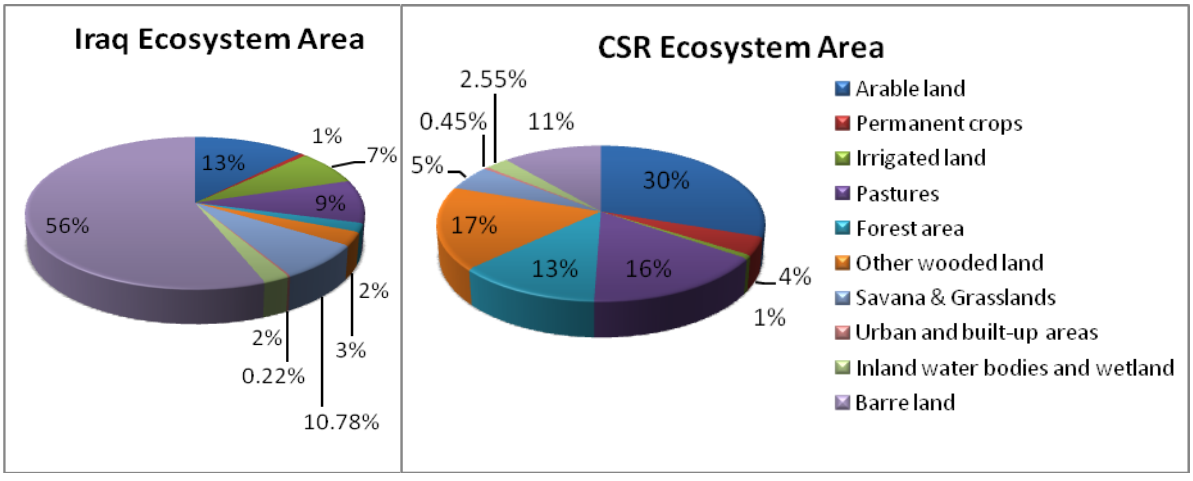


*The historical land use derived from Chapman, and land use of 2000, from FAO/WFP (2003). Crop, food supply and nutrition assessment mission to Iraq

Figure 5.1: Land Use by type in CSR for year 1947 and 2000

Source: Author, 2010.

To give a clear view about CSR Ecosystem footprint within international context, see Figure 5.2 illustrating the ecosystem area of the year 2000 of Iraq and CSR. It is clear that the share of ecosystem distribution in CSR is richer in a comparison to the whole country.



* FAO/WFP (2003). Crop, food supply and nutrition assessment mission to Iraq. EPA and Earth Trend 2003 'Iraq Profile'

Figure 5.2: Ecosystem area by type in Iraq and CSR for year 2000

Source: Author, 2010.

The biodiversity resource, the same as other natural resource is strongly affected by natural and manmade effect in the CSR. The damage due to war and border conflict is one of the major threats to biodiversity in the area damaged the same way.

5.2.1.2 Water Resource under the Shadow of Climate Change

The CSR is climatically characterized by the cycles of drought and wet seasons. The cycle of drought lasts for 1-3 years, and occurs every 7-8 years in a cycle. As explained in the previous chapter, Climate Change Effect, after the ending of the drought period, the positive effect can be recognized all over the CSR. Nevertheless according to local metrological records, amount of precipitation (the Maximum and Mean annual values) are in declining trend. It is worth mentioning that a study by Jalal, J. covered renewable water balance depending on FAO data, and forecasted that for the next 10 year the renewable water resource (precipitation amount) will cover all the demand including agricultural demand. The international and local model and studies indicates positive effect at N and NE belt of the CSR, while in the S, SW and W part (alluvial plain) the damage of drought on crop yield is quite high. Meanwhile, the water scarcity problem is not a risk for the CSR but due to the important footprint of CSR in the watershed issue and the basic theory of sustainability, this aspect must take high priority at the regional scale investigation.

As a result of the semi-arid weather condition at national scale, water can be a restrictive issue for growth, particularly in the middle and S part. This shows that potential wellbeing effects can be sever due to climate change. Since Iraq depends greatly on cross-border water resource flow, it can be extremely impacted due to decrease in trans-boundary water flow due to planned and newly built dams at the upper streams inside Turkey. In addition to that, some models forecast the decrease of renewable water resource. Moreover, with or without decrease in precipitation, the entire model showed that there would be increase in temperature by 0.6-2.1 °C that will affect the water balance and decrease existing resources.[217]. Therefore, enhancing the watershed capacity inside the country is gaining utmost importance now a day. Increase in temperature affects the wild life habitation dramatically, all the biodiversity resource are vulnerable in the CSR, but largely those that are allocated at the warmer parts (S and SW part) of the CSR.

With the large dependence of Tiger River, but only 54% of the total river basin area is located in Iraq.[218].The whole CSR totally is the Tigris River Basin contributing in total of 38-40% of the total river discharge. The main share of the river flow befalls in the flood period that is from February to June on the Tigris River. This indicates the degree of importance of CSR in addressing drought and water scarcity problem at a national level.

The CSR is highlighted under the expected increasing stress on water resources and the potential adverse impacts of climate change. However, at the other extreme is the vulnerability to flood in wet season. So planning is essential to tackle climate change impact on water resources at this spatial level. The mountain forests (CSR) forming the catchments areas of the Tigris and its principal tributaries “exercise a most important function in flood control and in reducing the silting up of river beds, reservoirs, and irrigation canals. It is very necessary, therefore, to maintain and to improve forest cover in the mountains so that its function in relation to flood control and erosion should not be further impaired”. [219]

[217] El-Fadel, M. & Bou-Zeid, E. (2001) *Climate Change and Water Resources in the Middle East: Vulnerability, Socio-Economic Impacts, and Adaptation*.
[218] Lightfoot, D. (2009) *Survey of Infiltration Karez in Northern Iraq: History and Current Status of Underground Aqueducts*:
[219] Chapman, G.W. (1948) *Ten years of forestry progress in Iraq.*

The decreasing trend in incoming precipitation and unsustainable use of ground water has critically decreased aquifer recharge and put the groundwater dependence as a water supply source in CSR at risk. Due to the geological formation and the type of rock in CSR, the availability of groundwater is totally reliant on the storing and rate of infiltration in the faults and fractures. Therefore, the importance of enhancing infiltration capacity by reforestation does not lay only on the enhancement of watershed area but also as an urgent reaction to diverse the effect of unsustainable use of ground water resource.

The drastic decline (drying up) of Karez within a few years in the CSR, due to the over pumping of aquifer and drought effect. It is a strong indication of unsustainable use of ground water resource. Mostly, the old part of cities was totally dependent on this old, sustainable and effective infrastructure up to the beginning of this century. In addition, numbers of villages that are totally dependent on this kind of infrastructure are affected badly particularly under the drought effect. These were due to several reasons, but among the most effective ones was the KRG policy in 2004, permitting people to drill wells, which led to the decline of this system.

5.2.2 Cultural Resources

The cultural heritage is dealt with from a historical point of view, in which those typologies are highlighted which have significant historical value, have effective influence on the tourism sector, and on natural resource management, particularly water.

As it has been described in section 4.1.2.1 the historical sites are from a wide span of time starting from Middle Paleolithic Period the era of Neanderthals and Cave dwelling (Shanader Cave)to living in plain and agricultural civilization (6750 BC at Jarmo) then down to more formal settlement (Erbil Citadel 7000 ago). This unique combination of human legacy and humankind civilization is one of utmost important in terms of cultural heritage preservation; since it is not just a local legacy; it is belonging to humankind as a whole. This unique and significant chain can be integrated in a way to be a vivid **Museum Of Civilization**. Moreover, this can be combined with the natural landscape with important scenic value.

The Erbil Citadel is the only case wherein a policy and action plan has been set for its restoration and preservation, with the aim of becoming temporary WHS and preserving the Citadel Town, KRG together with UNESCO. The other extreme is the Kirkuk citadel, where nothing has been undertaken to preserve it but rather the former government accelerated its destruction and deterioration. On the other hand, the large number of mounds that spread through CSA outside built up area is of major concern, since deterioration due to natural weather effect and human activity. The plain of Makhmur is classified by the archeological team in the University of Heidelberg as the place that has several radiological mounds. However, on the ground, due to the lack of experience, interest and all political situations, those mounds have not been identified. Since there is a dense activity like agricultural and oil industry in that area, necessary and serious step have to be made for avoiding total destruction and demolishment. That is why for achieving multi-functionality this layer will be analyzed with other in developing the GI plan.

5.2.3 Potentials and Weaknesses

To establish a baseline for identifying more detailed basic GI components that form ‘Hubs’ and ‘Links’ and analyzing them, is of basic and fundamental process. Each site or case study area will differ according to its specific characteristics, but will nevertheless work within an academic and

structured frame. It is important to work according certain approach and planning principal in which in this paper identified under the umbrella of GI concept.

In order to evaluate the importance of the CSR, the potential and weakness of the CSR are illustrated to give a clear understanding and quick overview. Then the argument of where and how GI concept can fit the current state of the CSR is investigated.

To accomplish this purpose on the base of the data that has been presented and analyzed at the regional scale the following list of potential and weakness of the CSR is illustrated as presented here in below:

5.2.3.1 List of potentials of CSR

- The geographical and climatically combination of the CSR made it an important area in terms of water resource management.
- The unique Geological and hydro-geological characteristic and the karstification characterize the CSR, made it sites of distinctive scientific interest.
- The near historical richness of vegetation cover and forest area of the CSR made the revival and restoration of this resource feasible.
- The economical booming of the KRG particularly made Strategic concept of GI feasible and adoptable.
- The natural landscape, cultural heritage and security state combination of the CSR made it a hub for local and national tourism.
- The importance of cultural heritage and historical legacy of the CSR that cover a large part of the area that is internationally known as “the cradle of civilization” made it a sites of special scientific interest and attractive place for tourism.
- The unique geomorphologic, natural landscape and richness of biodiversity combination of the CSR made it an important place for Eco-tourism.
- The richness of biodiversity, Flora and Fauna, Moreover, having 20 spices that endangered globally made the CSR to have important footprint in biodiversity and natural preservation domains.
- The potential of enhancing, activating environmental and protection policy at both governmental and community levels.

5.2.3.2 List of weaknesses of CSR

- The threats on natural and human dominated landscape due to the climate change effect made the CSR a vulnerable site.
- The Water scarcity problem mainly at national level at to lesser extent at regional level made the CSR of special interest in this concern.
- The flood risk in wet season inside and outside the CSR made it an important site according to GIP principal.
- The threats that constitute a real threat to species, natural reserves or distinct habitats, made the CSR a hot spot that need urgent intervention.
- The deforestation due to human use fire risk made the CSR one of the most affected areas in terms of erosion and loss of natural resources.
- The absence of comprehensive and integrated planned conservation of important cultural heritage and archeological site threaten this important resource in the CSR.

- The inactiveness of legislative and institutional practices and experience in the Environmental and related domains due to the dramatic political situation in the country.

On the base of listed potential and weakness, it can be concluded that to address the problem at this scale, it is not feasible and implemental to deal with each separately, but rather it should be dealt with comprehensively. Therefore, to develop a plan that could address the problems, boost the potentials at the same time achieve multi-functionality benefit, is achieving the balance between the main pillars of sustainability 'Environment, Society and Economy'. Of a counter degree of importance is the issue that can be addressed within GIP concept at regional scale. Accordingly and to answer the main argument where and how the GI concept can fit CSR specific characteristic, the general concept of the plan will be established.

5.3 Physical Analysis

5.3.1 Green Infrastructure Typology

Due to the variety and wide spectrums of assets that GI covers and deriving from the analysis of natural and cultural resources in CSR, the site-specific GI typology is identified as shown in table below.

Table 5.1: Main and specific GI typology in CSR

Source: Author, 2010.

Main GI Typology	Specific GI Typology
Designated Landscapes	National park Areas of Outstanding Natural Beauty Sites of Special Scientific Interest National Nature Reserves Scheduled monuments
Transport corridors	Rivers and canals
Managed landscapes	Woodland Agriculture and horticulture
Recreational landscapes	Lakes Streams

5.3.2 Network Identification

GI plan is the network of greeneries that provide multi social, economical and environmental benefits. On this base, the basic and main principal of identifying the network is multi functionality principal, although at the regional level the prioritization policy is one of the basic concepts of GIP. Even though the network cannot be totally an inclusive attempt to preserve the significant natural and cultural resources will shape the backbone of planning and developing GI plan. To formulate a base line the two main components of network (Hub and Corridor) will be investigated.

5.3.2.1 Patch Identification

Due to the degree of importance of existing component that have potential to be designated as Hub, at the regional scale, In this section the author will identify and allocate the specific component and give justification on the light of literature review.

As defined before by Mark A. Benedict patches (HUBS) "anchor GI networks and provide an origin or destination for wildlife and ecological processes moving to or through it." Under the light of this definition, the areas of high value of biodiversity and ecological process must be taken as targeted assets.

Conservation of biodiversity is a major international and environmental issue now a day. To identify endangered species and their ecosystem, special research and investigation should be carried out. Nevertheless, the species are contributing to ecosystem in different way, so in biodiversity conservation and preservation policy different approach like "Single species potential habitat" in which dealing with species and their habitat dominate by single kind. In addition, the approach of "species richness" which examines a wide range of spices in same habitat can be adopted. [220]

The survey process by Nature Iraq, dominantly adopted "Conservation Concern" (CC) and "Conservation Significant" (CS) category approach that comprises "globally threatened species; Iraq endemic and near-endemic species; species known to be declining in all or most of their range; species for which Iraq has a significant Middle East breeding population, and species for which Iraq is known to have a globally important wintering population." It is worth to mention that these criteria are evaluated and developed by the expert Richard Porter in Bird Life International.

Key Biodiversity Areas (KBA) is defined by Nature Iraq as "sites that are large enough, or sufficiently interconnected, to support viable populations of the species to which they are important". The KBA selection procedure applies a set of four criteria that have been established for the evaluation of surveyed sits. The developed criteria centered on the presence of four sorts of species that site-specific conservation process is suitable. The criteria were "Globally threatened species, Assemblage of restricted-range species, Congregations of species that concentrate in large numbers at particular sites during some stage in their life cycle, Assemblages of biome-restricted assemblages". [221]

While the assessment of each potential site as KBA is based on the "single species potential habitat" approach to some extent, but nevertheless in identifying and selection of the KBA sites the "species richness" approach was the base their decision.

The author will use the same KBAs as the patches (Hub), due to the richness of their criteria and comprehensiveness of their assessment, thus beside that, the meted they adopt is quite up to date and supervised by specialist and expert in conservation policy internationally. Moreover, the strong link between biodiversity principal that has been taken as one of the basic functions of GI, as mentioned in literature review. The integrity to the theoretical part can be summarized by: Biodiversity conservation policy, identification of "endangered spices" and "nature conservation" policy. In addition to KBAs list, another important area Hawiga marsh (65 km S of Kirkuk city), that has been identified by Bird Life International as one of the significant habitat for birds (Vanellus indicus and V. lrucurus) is added to the list. Figure 5.3 shows the Key Biodiversity Areas (KBA) in the CSR.

[220] Kellert, S.R. & Bormann, F.H. (1991) *Ecology Economics Ethics: The Broken Circle*.

[221] Ararat, K., Hassan, N.A. (NI), Rahman, S.A. (UofS), Nature Iraq & Iraqi Ministry of Environment (2009) *Key Biodiversity Survey of Kurdistan, Northern Iraq*: *Site Review - 2009 Survey*.

Hubs could be "reserves, managed natural landscapes, working lands, regional and national parks and preserves, and cultural, historic, and recreational sites". The reserves and national park have been covered through KBAs identification and to less extent the recreational site are included as well. The wide range and variety of GI competent with high potential of conversation, preservation and cultural/historic/recreational value exist in the CSR.

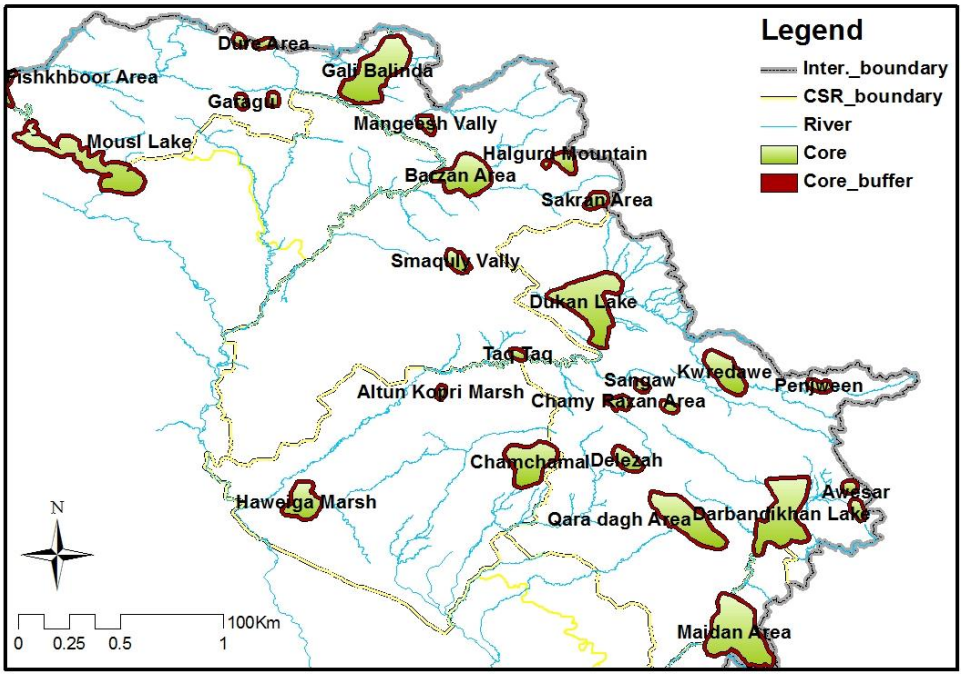


Figure 5.3: Identified core (KBAs) in CSR

Source: Author, 2010.

Large numbers of GI component that have been mentioned have high potential to be designated as Hubs at regional level; the author consider the same list of KBAs with certain addition that has been mentioned. This is to enhance multi-functionality concept and giving priority to certain GI typology at the same time to grantee the feasibility of the outcome plan. Since identifying, a large number of Hubs will scatter the effort and weaken the implementation feasibility due to economical restriction.

It is important to remind the J. Ahern definition of Patches that "provide multiple functions including wildlife habitat, aquifer recharge areas, or sources and sinks for species or nutrients." Therefore, another utmost important function that can be integrated is aquifer recharge areas.

Under the shadow of climate change and the necessity to address flood and water scarcity problem, moreover, uncontrolled hydrological projects (Dams) by Turkey is making the water shed area inside the country one of the most important strategy in mitigating and adopting policy.

Since "GI comprises all environmental resources, and thus a GI approach also contributes towards sustainable resource management". [222] In this concern and due to the degree of importance of CSR at the national and regional scale, the watershed management policy can be integrated in developing the GI plan concept. That is why this layer will be dealt with at a policy level and spatial level.

[222] Davies, C., MacFarlane, R., McGloin, C. & Roe, M. (2008) *Green Infrastructure Planning Guide*, *Version 1.1*.

GI is a means for managing river in flooding, through providing water storage, retention areas and enhancing infiltration capacity. [223] Where the high vulnerable areas to flood are integrated in two ways to give the high degree of importance, firstly it has been covered as one layer that for identification of corridor. Secondly, it will be proposed as a reforestation area with introducing clever water management (e.g. storing of winter precipitation in underground, swales and artificial pounds) nearby settlements was it urban or rural. Men while at this level of investigation only reforestation and protection policy will be covered.

5.3.2.2 Gap Analysis

The ecological network concept for maintaining biodiversity can be achieved by connecting and integration of conservation areas or areas with significant biodiversity through corridors and links at a spatial scale. GI can link fragmented habitats and landscape features to put on to earth ecological network.

However, the KBAs identification achieved mostly impotent aspect of Biodiversity conservation, but the inclusion policy of landscape diversity within the umbrella of biodiversity and ecological network that have been stressed in literature review have not been covered by the Nature Iraq proposal. Since their conservation, policy only depended on “size and support of viable population that are distinct”. In other words, it only covered “size and variety” and the “connection and dynamics” of ‘patches’ were not included and covered in their work.

Moreover, to achieve ecological heterogeneity, in multi-functional landscape there should be a link between biodiversity and cultural diversity. [224] This link is obviously through gray infrastructure roots that are spread like a spider net in the CSR. While this links in the environmental and ecological context is prohibiting negative impact in this concern due to the absences of environmental dimension in planning process and lake of environmental impact assessment process.

5.3.2.3 Corridor Identification

Developing a network of corridor and links to achieve the basic pliers of biodiversity conservation “size, variety and dynamic” is of great importance. Nevertheless, developing corridors need comprehensive research and study at the designated area. In addition, it varied widely due to the targeted spices. That is why the author adopts the basic principle in this concern combined with GIP concept. Moreover, to achieve the concept of connectivity, integrity and multi functionality the author develops a network of corridors with verity of function.

While dealing with conservation, preservation and protection other aspects comes along with them, that are related to economies and ethics disciplines. Concerning the former is related to the feasibility and sustainability of the project, while the latter deal with the sense of responsibility in protecting nature, culture, and history as a legacy for current , future generation and humanity as a whole.

5.3.2.4 Institutional Analysis

The everlasting gap between law legislation and law execution reflects the inconsistence between legislative and executive institution. However, the present forest law in Iraq was promulgated long ago, but neither former Government not current Government applied or worked by those low.

[223] Bartens, J. & Mersy Forest Team (2009) *Green Infrastructure and Hydrology. Mersy Forest.*

[224] Mander, Ü. , Wiggering, H. & Helming, K. (2007) *Landscape Tomorrow: Multifunctional Land Use, Meeting Future Demands for Landscape Goods and Services*.

Moreover, officially the importance of mountain forest in CSR as an important strategy in mitigating and adopting policy in dealing with climate change related effect on water source are declared by the current Iraqi Government, but no action on the ground took place. Instead counter policy like village natural landscape distraction were adopted by former government, while the by current Government up to now no effective strategy had been put in to action at a national level.

The KRG emphasizing on the sustainable use of water resource, but the counter policy by KRG in 2004 by permitting people to drill well without limitation to address the shortage in demand for water resource in capital cities, were adopted which cause the degradation of sustainable older system (Karez System). In addition, it is a clash between technology and traditional resource, while the traditional recourse was totally sustainable by depending on renewable water resource (Rainfall) and gravity system for transferring and distribution.

One of the basic principal in GIP concept is stated, "The provision of publicly accessible natural green space is a vital component in securing benefits for communities where this can be balanced with the needs of private landowners and biodiversity conservation objectives". While in CSR the balance concept is absent in most of the site of high value due to institutional gap.

Kurdistan environmental and forestry police forces protection to sites and controls abuses like in the Qara Dagh site in Sulaimaniyah, and Barzan in Erbil. Moreover, in the 2009 survey Nature Iraq put both site in KBA list in CSR. At the same time due to the tourism plan Qara Dagh is developed as a national park for recreational purpose with a wide variety and uncontrolled use. Since this may affects patches (Qara Dagh) dynamic species viability that may cause diverse effect and increase degradation. This can be seen as a clash of planning and vivid evidence of lake of institutional integrity.

While Barzan site in Erbil can be regarded as both physical and institutional gap at the same time. The Area is owned and resident by the family of Barazany the current president of KRG. Although this enforced the Kurdistan environmental and forestry police to a very good extent especially those including hunting policy, but at the same time it weakened and affected negatively biodiversity conservation principal. As highlighted in literature review the part about biodiversity as an ecosystem services, "expanded approach to biodiversity should include genetic and landscape diversity"[225]. This is of major concern and against integrity concept that is of the same degree of importance as conservation. Barzan site has particular importance that distinguished it from all other KBAs, that it has a most distinct globally vulnerable Wild Goats (Capra aegagrus). The genetic diversity of these spices is of major concern, since it is the only area in CSR left with this distinguishable species. Therefore, again, this represents gap and clash of institutional power. Moreover, this is also contradicting the basic principal of "**environmental equity**" and "**social justice**".

Again, the clash of tourism interest and lack of integration in planning is reputable in so many natural area of biodiversity importance. Most of the important site with very high scenic and rich biodiversity value attracted unsightly development and tourism. Sites like Ahmed Awa, Bekhal Falls and Gali Ali Beg, in which uncontrolled development and unmanaged tourism stress, lead to drastic species degradation and pollution specifically water pollution. [226]

[225] Samson, F.B., & Knopf, F.L. (1996) *Ecosystem Management, Selected reading: Biodiversity and Ecosystem Function (Paul G. Risser).* pp424, 331, 281, 282.pp424, 331, 281, 282.

[226] Ararat, K., Hassan, N.A. (NI), Rahman, S.A. (UofS), Nature Iraq & Iraqi Ministry of Environment (2009) *Key Biodiversity Survey of Kurdistan, Northern Iraq: Site Review - 2009 Survey.*

5.4 Identifying focused ecosystem services

The core strategy concept at regional level will be conservation, connectivity and resource management. In other words the environmentally dominated policy but nevertheless both 'Social and Economical' will be a natural outcome of the plan, which will not be covered in the course of this paper. That is why the ecosystem services that is adopted as a base for GI plan development are focused on Biodiversity preservation, Landscape Heritage and Historic Environment Conservation and Managing Hydrology particularly water resource management, see Figure5.4.

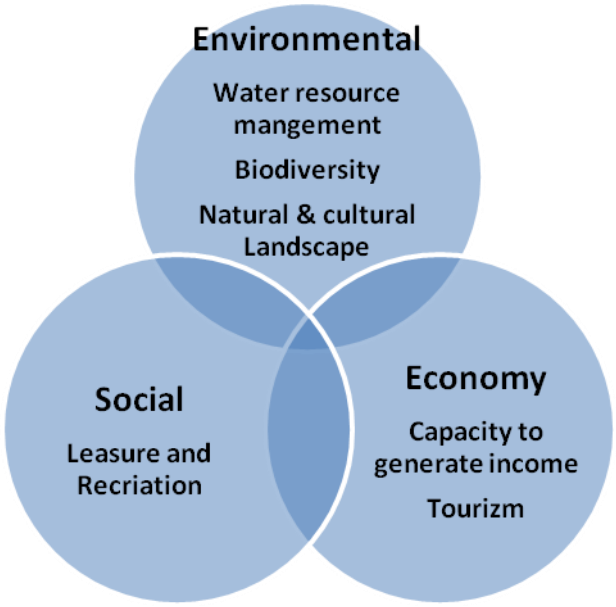


Figure5.4: Main ecosystem services at regional level

Source: Author, 2010.

5.5 Proposed Strategic GIP at a Regional level

5.5.1 GIP Concept

The developed plan advances the concept of "borderless communities" since natural landscape, species biodiversity and connectivity do not know municipal or governmental border. The developed plan helps to identify the regional resources, by creating a GI base map, then developing a concept for integrating and connecting this resource spatially.

The aim is to develop the network of corridors in between the KBAs maximizing the benefit outcome, to enhance multi-functionality and most importantly achieving the main aim of connectivity and integrity. As it has been illustrated before a variety of GI competent with high potential of conversation, preservation and cultural/historic/recreational value exist in the CSR. In order to obtain economical feasibility and ethical responsibility, corridor identification will not be exclusively bounded to wildlife movement and biodiversity conservation. The corridor in the context of this investigation is designed to achieve the aim of conservation, preservation and protection of resources in its wider context, including biodiversity, resource management and cultural/historic/recreational resources.

LINKS are the parts that provide dynamic function and make GI networks to work. [227] Links can come in variety of function size and assets, but in the course of this paper, it is specified like landscape linkages, conservation corridors biodiversity and wild life movement corridors at specific areas.

The layers that are identified to give weight of identification of the corridor can be illustrated as indicators used for planning decision and ArcGIS9.3 software as a planning tool. A set of nine layers that cover natural heritage and cultural heritage resources have been used.

The first set that consist of six layers namely '**Mound site, Historical site, Landscapes of high value** which are hubs for regional and national tourism, **Karez, Flood zone and Streams** (watershed area) are used. In the aim that the designed corridor pass through the more dense area that they cover for this reason the density function for analysis have been used. See Figure 5.5 and Figure 5.6 that illustrate spatial density distribution of each layer throughout the CSR. It is worth mentioning that stream rout density map (Figure 5.6) can be used as a base for watershed reforestation policy, since it gives a clear view of areas of highest stream formation.

While the second set consist of three layers namely '**River, Road and Buildup area'**. It has been used with the same basic principal with the difference in identifying the weighted function by the 'Euclidian Distance' function. To give various weight according to spatial distance from the selected layers. See Figure 5.7; illustrate the weighted spatial distribution of designated layers.

[227] Benedict, M.A. & McMahon, E.T. (2002) *Green Infrastructure: Smart Conservation for the 21st Century.*

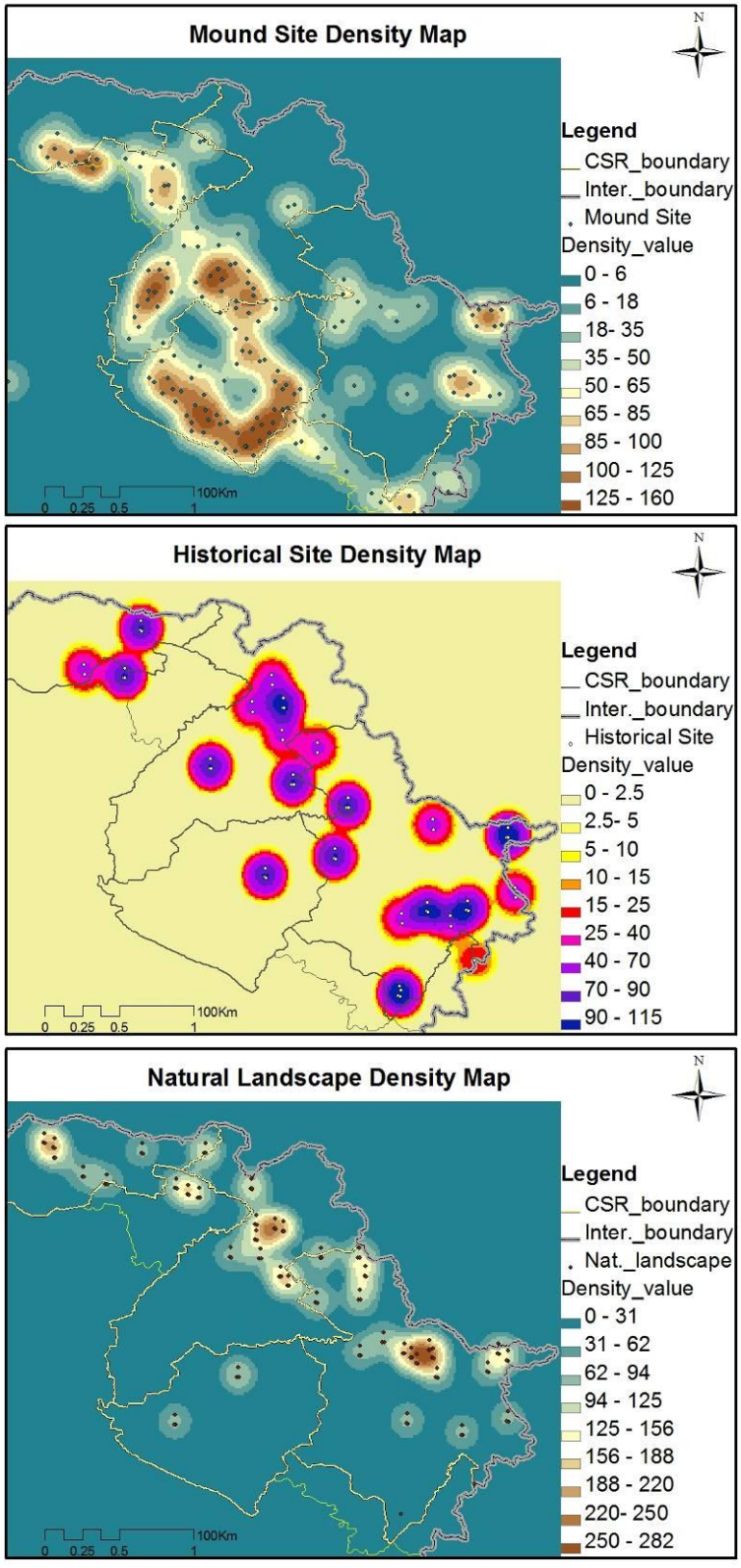


Figure 5.5: Spatial density distribution of Mound, historical and Natural landscape area (T, M and B)

Source: Author, 2010.

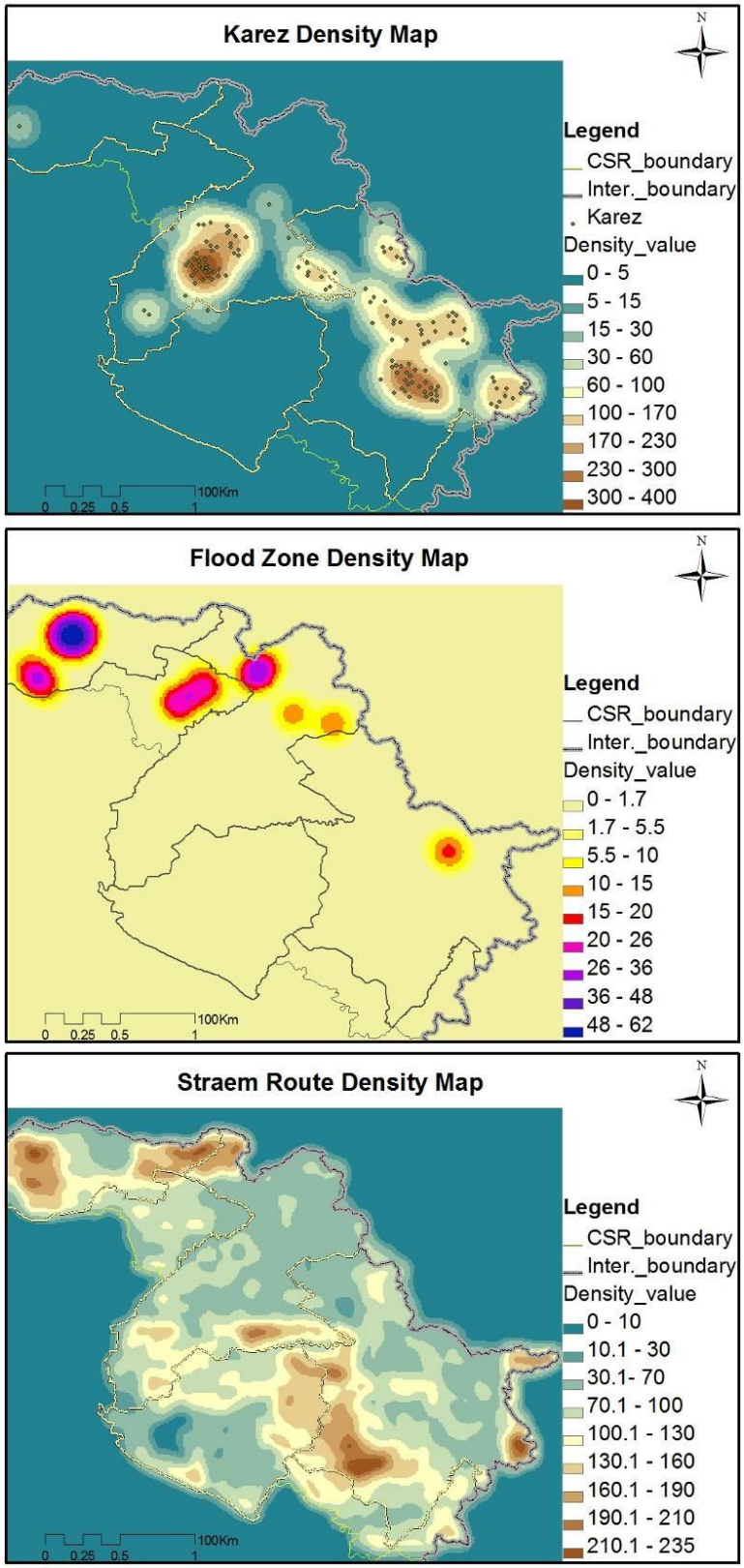
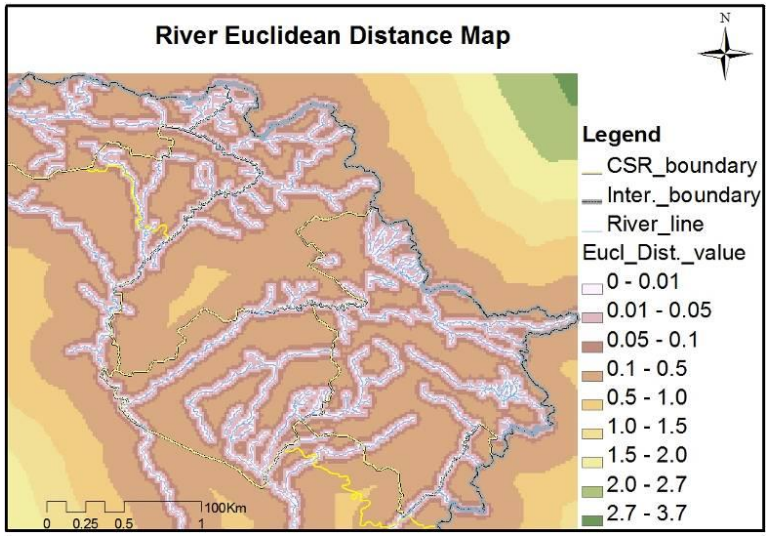
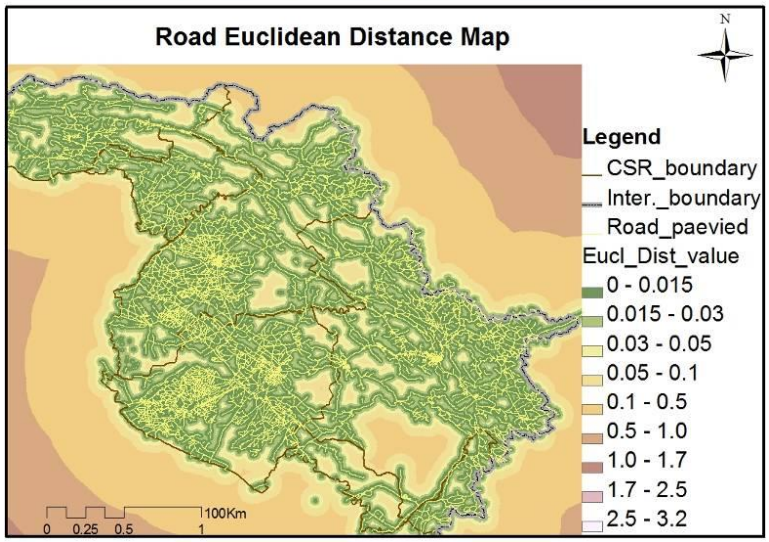


Figure 5.6: Spatial density distribution of Karez, flood zone and stream route (T, M and B)

Source: Author, 2010.





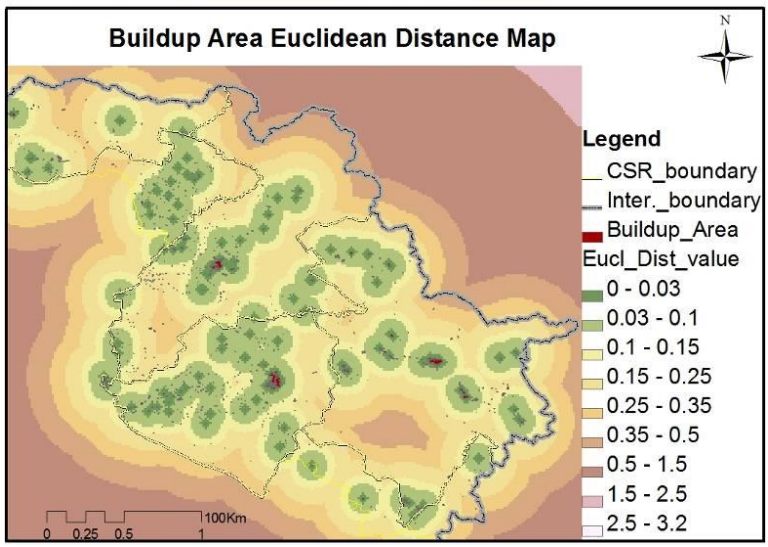


Figure 5.7: Euclidean distance distribution of river, road and buildup area (T, M and B)

Source: Author, 2010.

Each set of identified layers have been summed up with applying equal weight to all indicators. To overlay different layers with different analytical function, first, the impedance layer of each set has been developed then the both set of indicators are overlapped. See Figure 5.8 and Figure 5.9 show the total sum of density distribution and impedance layer for each set of indicators.

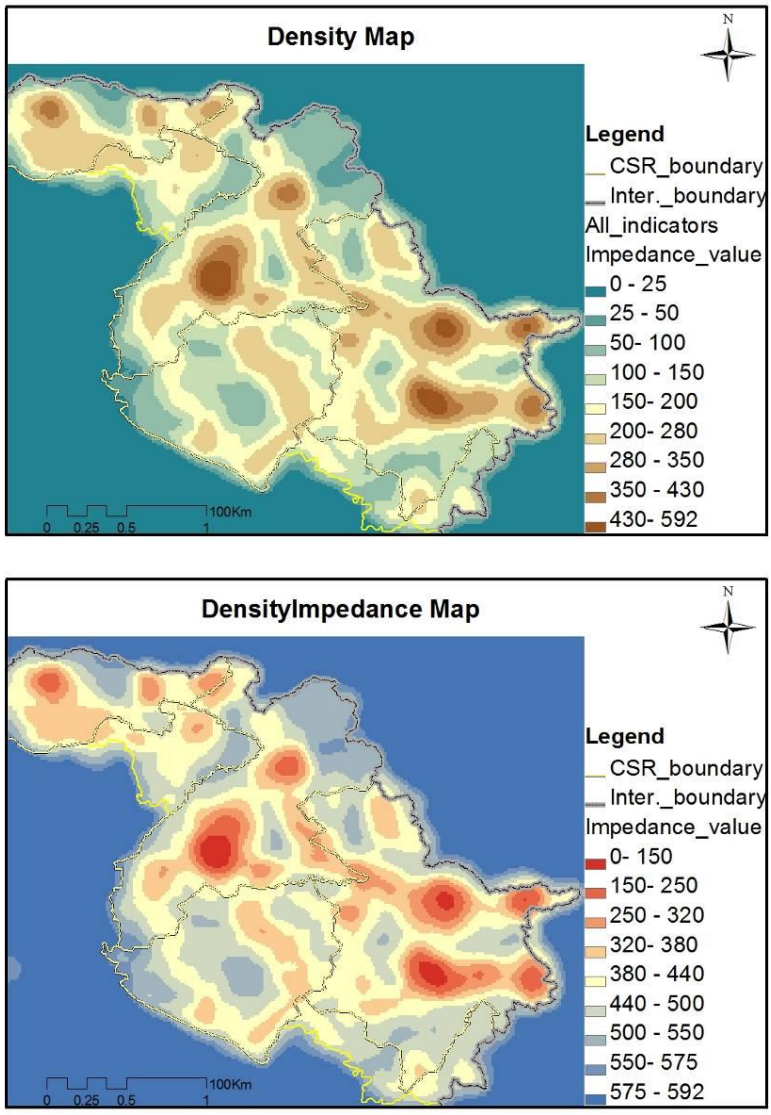


Figure 5.8 : Density and Impedance distribution of first set of indicators

Source: Author, 2010.

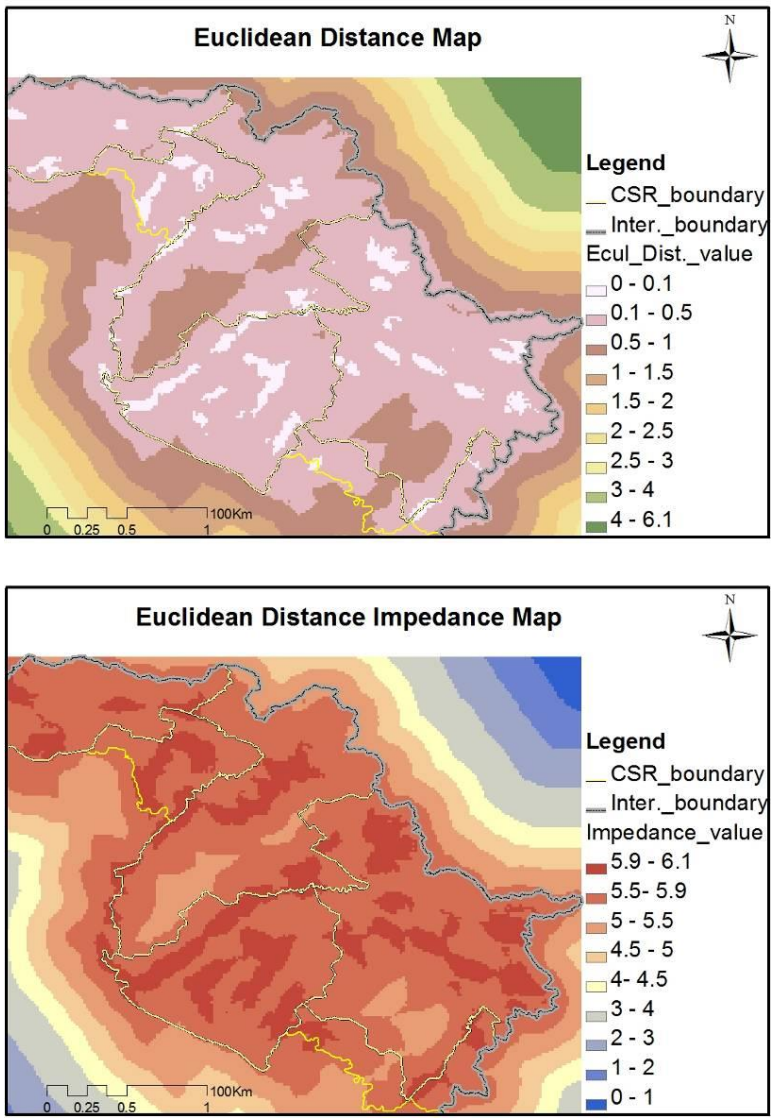


Figure 5.9: Euclidean distance and Impedance distribution of second set of indicators

Source: Author, 2010.

To overlay different impedance layer, the normalization of scale have been applied to the second set of indicators (river, road and buildup area), so that a comparable scale of impedance value to be put against each other. Then the total sum of all layer created to be used as a base layer for giving weight for corridor identification, see Figure 5.10 illustrate impedance distribution for all layers.

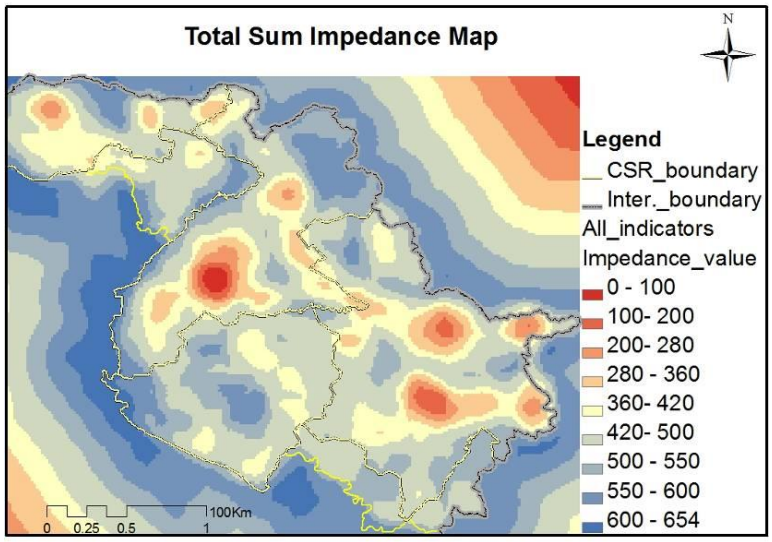


Figure 5.10: Overlaid Impedance distribution of all indicators

Source: Author, 2010.

To identify the corridors path the impedance layer has been used to give weight for the identification in-between different (seven set of source and destination) patches (KBAs) by using cost distance function. See Figure 5.11 as sample that illustrates a set of visual representation of analysis result with a clear indication of the identified pass (corridor) with a minimum cost distance value (maximum impedance value).

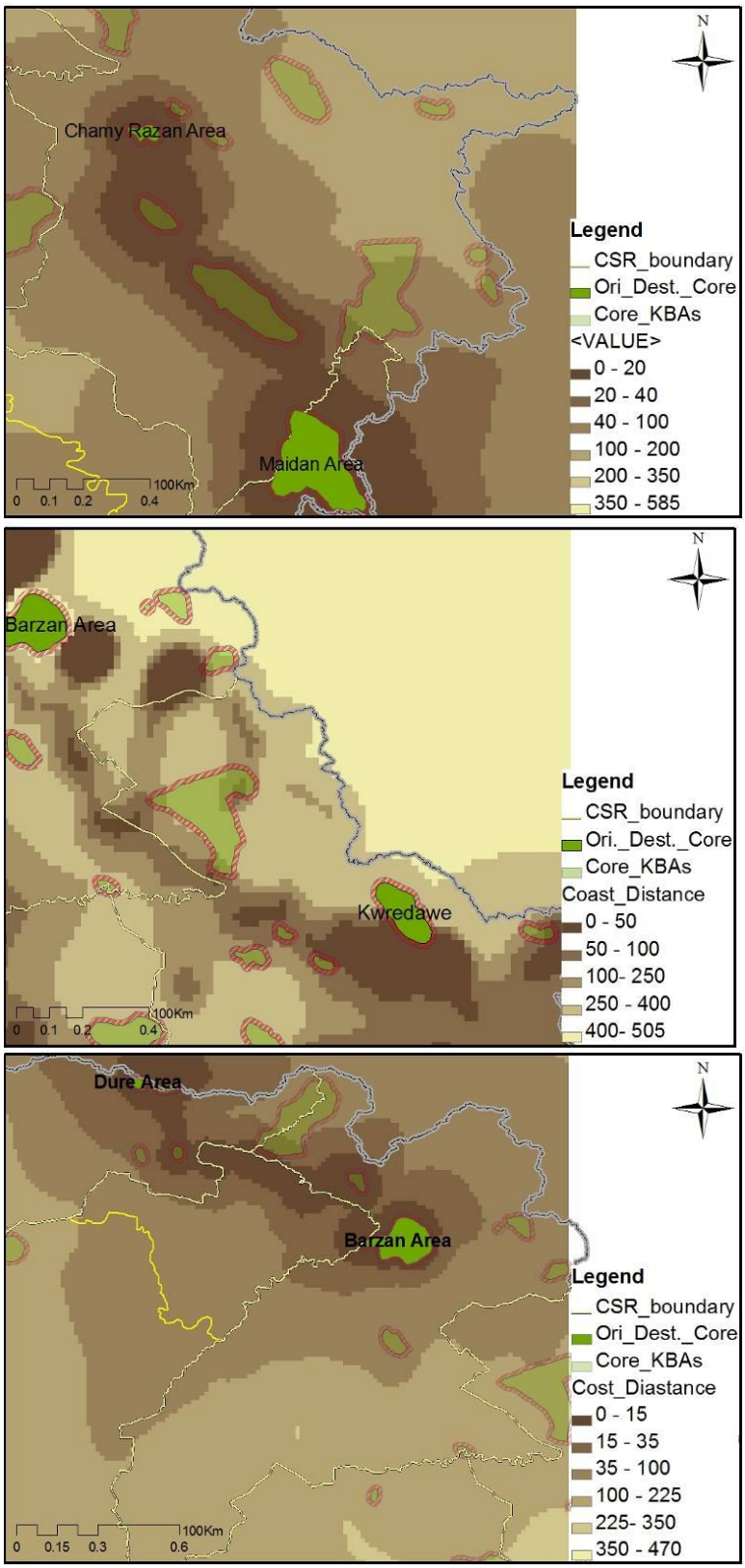


Figure 5.11: Identified pass (corridor) between different origin and destination core (KBAs)

Source: Author, 2010.

5.5.2 Proposed Green Infrastructure Plan

After identifying corridors between different patches a dynamic network that consist of hub, core, corridor and links have been proposed. In the designing the corridors the impedance layer used as a base while during the allocation certain other factor like priority to river side area have been taken in to consideration, in a way some designed corridors are acting as a riparian buffer for the existing surface water (rivers). That will support both ecological and watershed function, thus regardless of increasing the feasibility of the plan in those particular areas. See Figure 5.12.

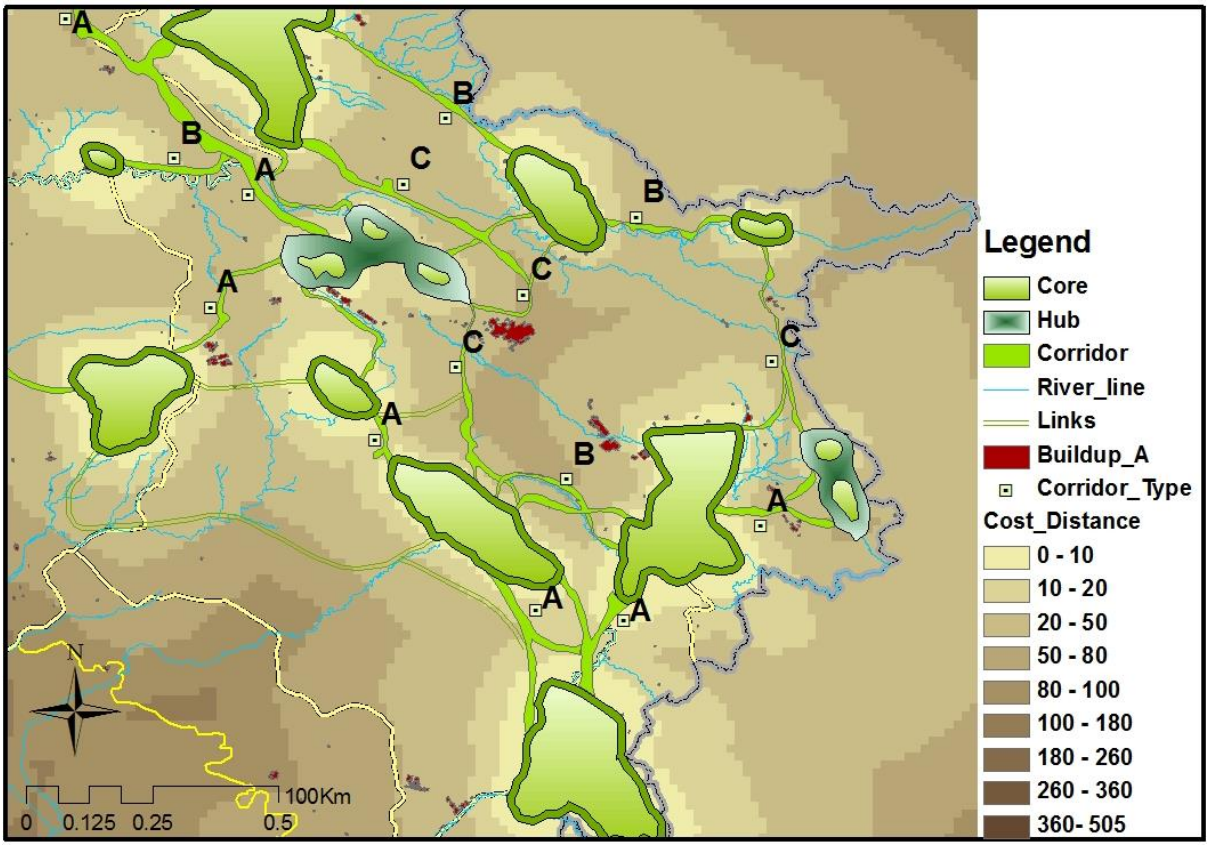


Figure 5.12: Overlaid proposed GI network on identified pass by Cost distance function

Source: Author, 2010.

The corridors designed with different functions, mainly represented with three categories: wild life movement function (A), Conservation function (B) and landscape function (C). At the same time any corridor may have three or more functionality, but the identified function is the dominant function that must be designed to perform. For KBAs like (Maidan and Barzan area) that have been identified as a hot spot in Gap analysis for connectivity and integration, the corridor is designed as category (A). The former area is hotter in a comparison of the rest part of the region. As mitigation and adaptation for climate change effect particularly increase in temperature, it is so important to provide corridors for wild life movement. See Figure 5.13, which illustrated the proposed GI plan at regional level.

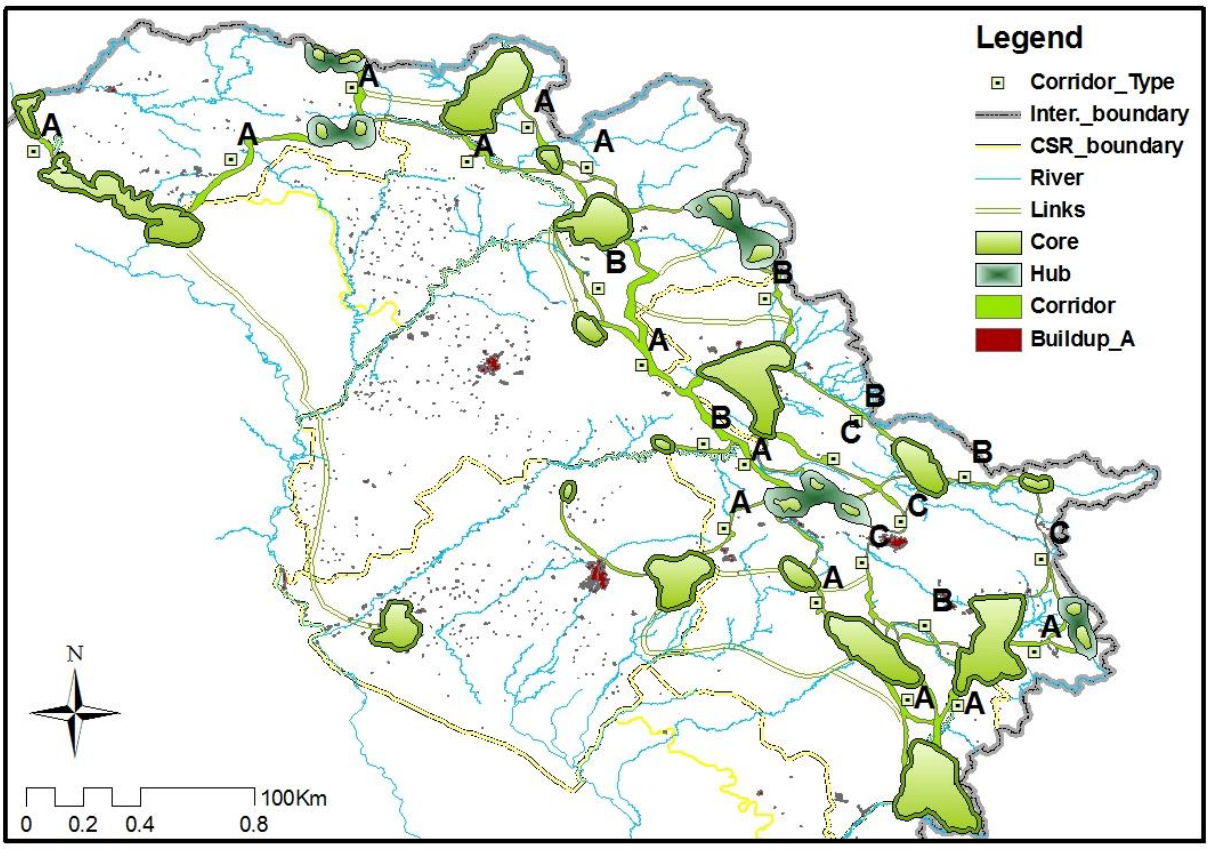


Figure 5.13: Proposed GI network at a regional level

Source: Author, 2010.

5.5.3 Proposed Green Infrastructure Plan within Regional Context

To have an overview about the proposed network within the natural resources of the CSR, the GI plan overplayed on the important layers. A set of five main layers namely Land cover, Watershed, Karst, Soil type and Land limitation have been developed with further detailed classification The proposed network set against each layer for analysis see Figure 5.14, illustrate the visual understanding of the analyses. The identified corridor and core are located on areas 72% and 61% correspondently within areas presently vegetated. Also they have located on areas with soil type 82% and 71% is suitable for forestry area. Within the land limitation, some limitation can be regarded as a positive aspect for this proposal such as low temperature, wetness and steepness. The finding also suggested that (according to the available set of data) the proposed plan have no salinity or low rainfall or rocky area. While watershed and Karst layer is covered with a high intensity. See table 5.2.ilustrated the detailed analyses result of the proposed network.

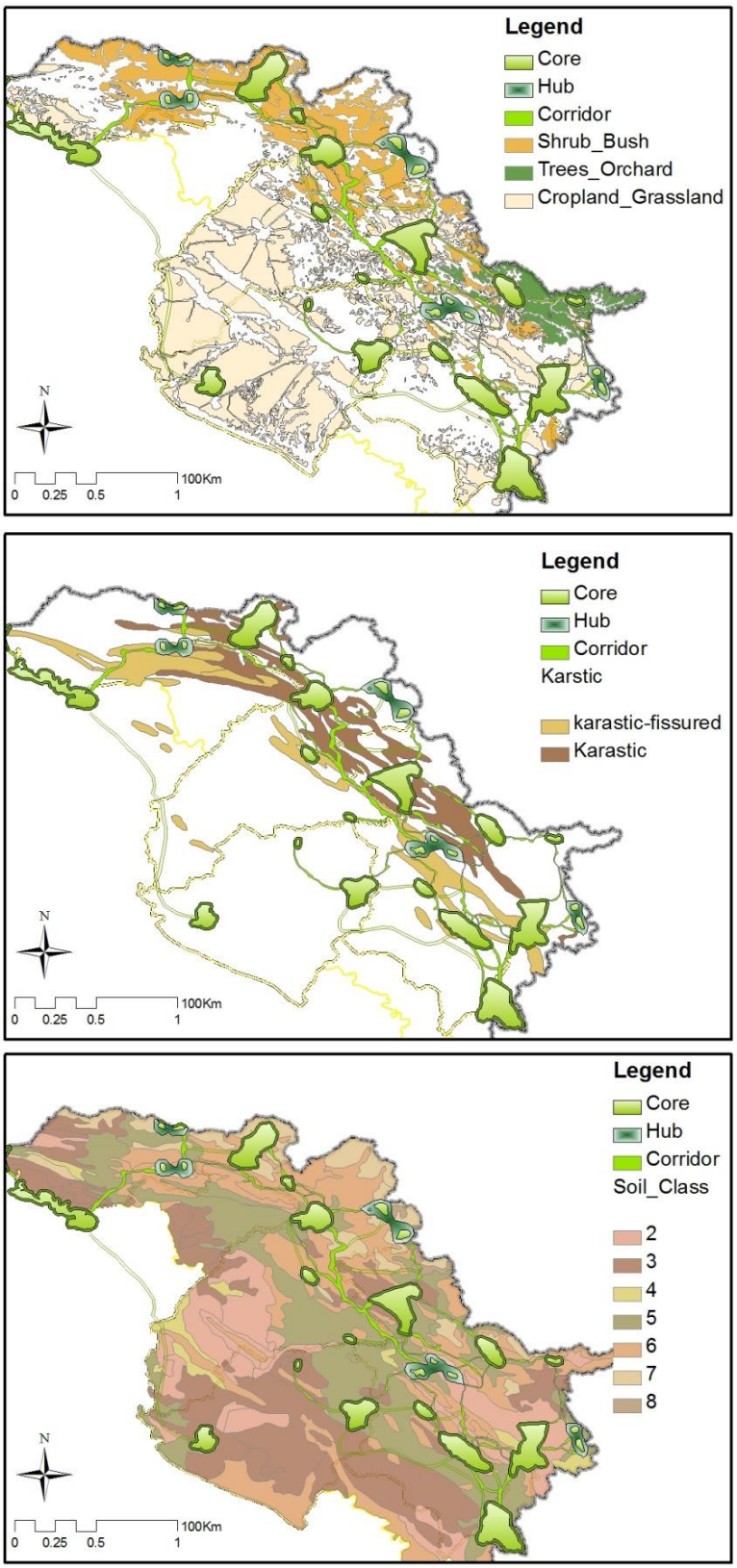


Figure 5.14: Overlaid proposed GI network CSRs natural resources land cove typology (T), Karstic layer (M) and Soil type (B)

Source: Author, 2010.

Table 5.2: Ratio of CSRs natural resources within proposed network

Source: Author, 2010.

Type	Specific Indicator	Corridor	Core
Land cover	Shrub and bush	46%	32%
	Orchards	8%	4%
	Cropland	18%	25%
	Bar land	28%	39%
Watershed		100%	100%
Karst	Karastic and Karastic-Fissured layer	96%	68%
Soil type			
	Class 2: good cultivable land with minor limitation in use	8%	7%
	Class3:moderately good cultivable land with minor limitation in use	11%	12%
	Class 4: land suited for limited cultivation	2%	3%
	Class 5: very well suited for grazing and forestry	33%	35%
	Class6: well suited for grazing and forestry	39%	24%
	Class7: fairly suited for grazing and forestry	6%	8%
	Class8: land unsuited for cultivation, grazing and forestry	2%	1%
Land Limitation			
	I: land limited in use due to steep slope	8%	12%
	e: land limited in use due to erosion	7%	15%
	w: land limited in use due to wetness	0.03%	6.6%
	s: land limited in use due to salinity	-	-
	c: land limited in use due to low temperature or snow cover	1%	1.7%
	d: land limited in use due to low rain fall	-	-
	t: land limited in use due to soil texture	6.3%	7.2%
	g: land limited in use due to high gypsum content	1.8%	14%
	e, l	10%	17%
	t, e	2%	2.4%
	r: land limited in use due to rock outcrops or high content of stone	-	-

6 Green Infrastructure Planning at Metropolitan Level

This chapter covers the main vision of the GI Plan in order to direct the reader smoothly to the core analysis part, the logic behind choosing certain ecosystem services and then the developing of plan. It covers comprehensive evaluating and analyzing the natural potential landscape resources and man-made urban green space in CSC, also identifying set of deficiency according to GIP standard. The author set a strategy to address adapting city to climate change and 'systemic' urban issues at the metropolitan scale according to GIP concept. Then evaluating the developed plan against the existing situation, the author adopted similar concept to Whitford, V. et al, by using 'Urban Ecological Index Module', after adjusting and applying it considering the availability of data and the local situation. Then under the light of literature review and depending on Arc GIS9.3 software as a planning tool and AutoCAD 2009as designing tool the chapter present developing GI Plan.

In the course of the section the Metropolitan scale will be the main course of the research, nevertheless the hierarchical special order will be covered since it is essential from strategic point of view.

6.1 Plan overview

The Urban climate engineering and improving quality of life make up the fundaments for investigating, analyzing and developing the GI plan at the metropolitan level in the CSC. Since GI entails metropolitan areas that functions and managed in an integrated and connected mode to maximize the ecosystem benefits, the city will be dealt with in terms of urban green network as well as landscape level at the periphery of the CSC to join forth of all related parties. The developed plan advances the concept of "borderless communities". In this level, more prescriptive details are requires to be layered the climatic condition in the built-up city basin, 'systemic' urban issues and the growth development pattern. This all together shaped the starting point for developing the GI plan at city level. On the base of geomorphologic setting and climatic context of the CSC, the main challenges and issue that to be studied have been identified accordingly. Urban climate and to lesser extent quality of life and water resource management identified as the most significant issue to be dealt with under the natural and manmade influence.

The proposed GI Plan for Sulaimaniyah (CSC) is an academic initiative at municipal level to identify and develop valued community green space resources. The plan brings together the city most important green space resources, including natural and manmade green resource systems such as streams, watersheds; working landscapes such as farms and managed forests; recreational and tourist sites.

6.2 Analysis of CSC

6.2.1 Natural resource

From a conventional landscape planning point of view, dealing with the basic elements fundamental for landscape planning are covered under natural resource of the CSC. Those fundamental elements like soil, hydrology (water resource) and climatic condition are in none substituted relation. Those have been dealt with comprehensively depending on the availability of data.

The soil of the CSC and particularly the area under investigation is characterized as Chestnut soil with self-mulching process and the presence of moderate organic matter. Accordingly, it classified as a good class for planting. While the mountainous soil can be classified as a poor class in this regard but the GI plan will not cover that area. It is worth to mention that Tourism Master Plan covers this part of the mountain portion and the reforestation process are undergoing. While according to landscape planning, the water resource must be renewable water resource, in other words totally dependent on precipitation. "Due to the availabilities of annual renewable precipitation of more than 450 mm needed by forest, rangeland and dry farming activities successful planting and productivities can be achieved" [228]

While regarding the climate condition in terms of temperature and other metrological aspect, the CSC can be regarded as a suitable zone for plantation and reforestation, although only at few month of hot winter special management is needed.

In this regard, the basic aim of dealing with this part is to emphasize the feasibility of greening in terms of natural resource in the CSC. To enhance planting indigenous tree species is strongly recommended in any greening process.

Landform is pivotal for the living conditions in the CSC. Large altitude variances over a narrow horizontal area and a noticeable topography are the consequence of geological formations and the erosion influence of the surface waters that constantly developes deposits layers in the city's basin.

Intense land use, over compactness and artificial sealing practices led to heat and pollutant emissions. This regardless of hydrological and aquifer problems due to local climatic, geomorphologic and man-made activity is make a challenge for the CSC.

This in addition to the global climate change effect, the CSC is particularly vulnerable to, overheating and flooding. Consequently, the air quality due to climate change effect and incremental trend in fuel combustion process (due to over dependence on private mobility and transport model shift towards more unsustainable mode) is causing serious challenges and having negative health effect.

Moreover, most of these karez (84%) are in Sulaimaniyah governorate. In Sulaimaniyah city, for instance, due to the topographic situation that enhanced the feasibility of this Sanharib (Karez) system old part of the city was totally dependent on this old, sustainable and effective infrastructure up to the beginning of this century. The city center up to few years ago, in certain neighborhood were totally dependent on that this regardless of the main park of the city (Azadi Park) for irrigation purpose. However, due to unsustainable management this environmental friendly, renewable sourced replaced by unsustainable use of groundwater.

6.2.2 Land Use

Land Use is a main activity that regulates the performance of the landscape regarding socio-economic function for instance `land based production, infrastructure and housing`. The degree of assimilation between the socio-economic provisions and environmental function comprising natural assets protection is determined by the pattern and density of the land use. [229]

The City located on the most ferial basin (Shahrazoor Basin); over the time agricultural activity and natural landscape have been decreased dramatically. According to principal of sustainable planning

[228] Jalal, J. (2008) *Natural Resources and Its Utilization for Agricultural Development in Sulaimany Governorate*. PhD. Thesis
[229] O'Farrell, P.J. & Anderson, P.M.L. (2010) *Sustainable multifunctional landscapes: A review to implementation.*

and socio-demographic trend, the GI in the CSC must have been in incremental trend, but due to so many reasons the trend of GI percentage are in decreasing range. According to the last Master Plan, the GI will be increased from 8% to 15%, while with including agricultural typology the total GI is decreasing from 58% to 34%. To give a clear understanding to the land use pattern in CSC area, see **Fehler! Verweisquelle konnte nicht gefunden werden.** and Figure 6.2 illustrate the existing and planned area of urban morphology categories of the CSC at present and future (2020) time.

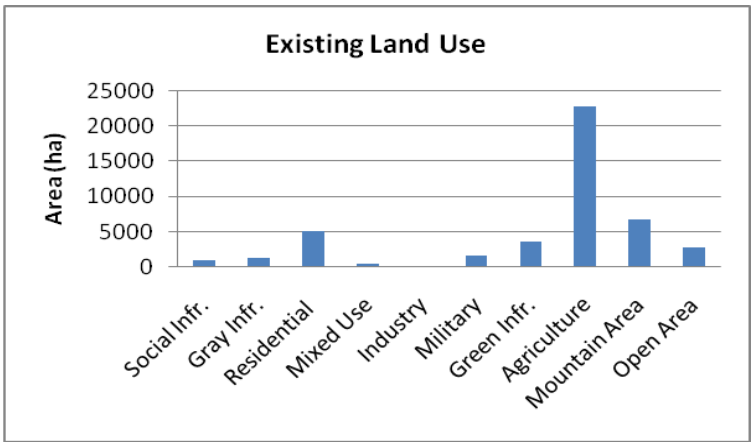


Figure 6.1: Area of existing urban morphology categories in the CSC

Source: Author, 2010.

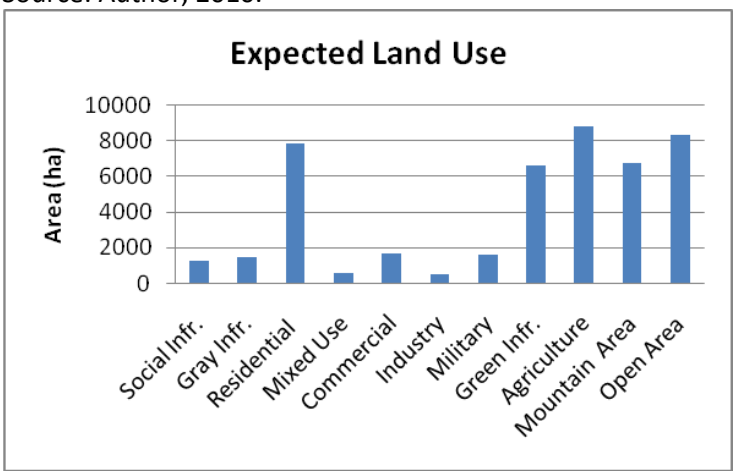


Figure 6.2: Area of planned urban morphology categories in the CSC

Source: Author, 2010.

The regional and national Performance of the city in terms of Urban sprawl and compactness is ranked high, but the city's climatic performance and its build environment can be considered poor and facing many 'systemic' challenges. The existing build up part inside 60m ring road of the CSC have reached their housing saturation point in their present configuration, see Figure 6.3 illustrating the population density at neighborhood scale. Also there are rehabilitation in so many part of the city, where the change is towered increasing floor space Index and decreasing Plot area ratio, in a way few or no open area and more floor at a plot level. This increase a building mass and cause negative effect on urban climate, in terms of thermal and air quality index. That will increase both thermal and air pollution in the city center.

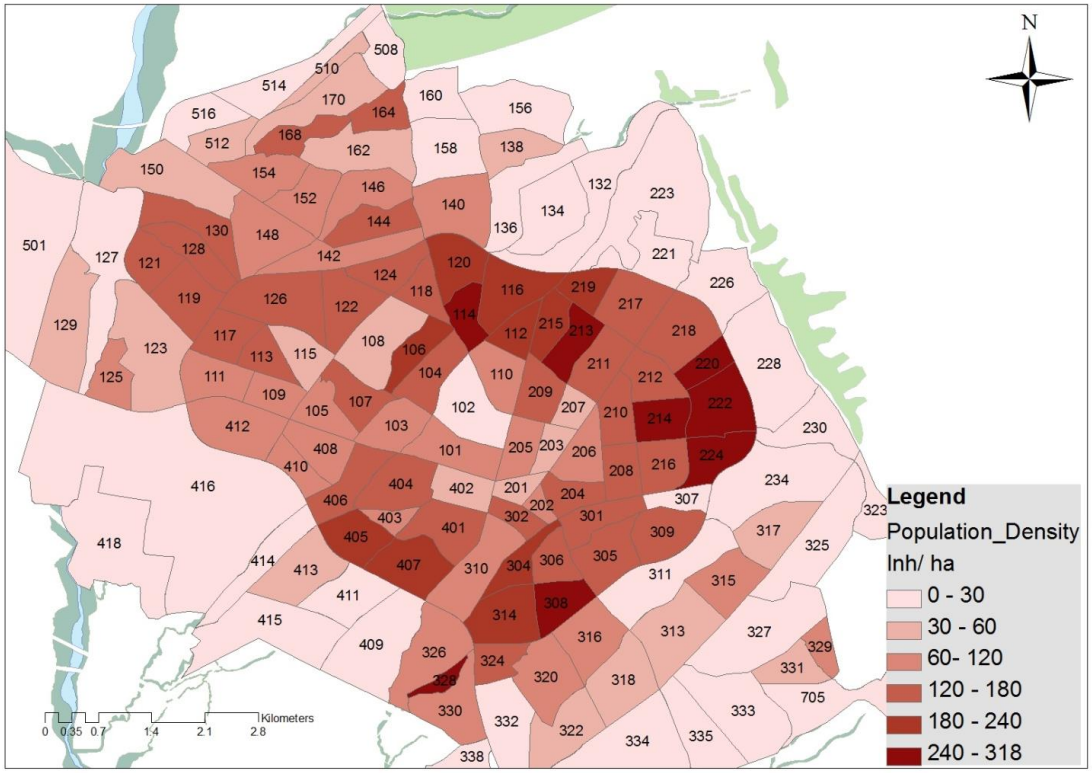


Figure 6.3: Distribution of population density at neighborhood scale in CSC

Source: Author, 2010 from Municipality of Sulaimani City data.

6.2.3 Potentials and Weakness

6.2.3.1 List of potentials of CSC

- The geographical and climatically combination of the CSC made it an important area in terms of Climatic Engineering.
- The fertile soil and availability of water resource that made the implementation of the GI plan feasible.
- Development.
- The CSC characterized by local down-slope winds that reduce the thermal and air pollutant in hot season.
- Rehabilitation is undergoing in so many part of the city particularly in city center.

6.2.3.2 List of weakness of CSC

- The High rate of urbanization, the considerable natural growth rate, and improving trend of GDP that causes CSCs rapid development.
- The low quality of local Climate of the CSC, particularly the one of built environment, like Urban Heat Island, smog and low air quality.
- The topographic and geomorphologic setting of the CSC that enhance flood risk in CSC.

- The lack of adequate green area in the buildup areas and the lake of principal of **social justice** in this regard.
- Blocking the natural wind travel route by over development in CSC.
- Wide spreading uncontrolled building development into the vicinity of the city of Sulaimaniyah, especially into the foothills of the surrounding mountains.
- Hillside development that have been and will thermally polluted due to dense development.
- Increasing building mass accompanied with rehabilitation process in the CSC.
- The cold and heavy winds (known as Rasha-Ba) are falling down hills side in winter.

6.3 Physical Analysis

6.3.1 Green Infrastructure Typology

Due to the variety and wide spectrums of assets that GI covers, it will be logical to shade light on the assets or typology that exists in the CSC. Therefore, the metropolitan area will be dealt with at two scale landscape scale and urban green space scale, for identifying the assets. While for connectivity part, both will be analyzed as one integrated unit.

Table 6.1: Main and specific GI typology in CSC

Source: Author, 2010.

Main GI Typology	Specific GI Typology	Specific GI Typology to CSC
Designated Landscapes	Areas of Outstanding Natural Beauty Algal-power Landscape	Mountain foot hills
Transport corridors	Blue-way Riparian Corridor Streetscape trees and planting	Qlyasan River Sarchnar and Chaq-chaq valley Streetscape trees and planting
Managed landscapes	Urban Woodland (Forest) Cemeteries Agriculture and horticulture	Foot hill forest Cemeteries Agriculture and horticulture
Recreational landscapes	Community Garden Urban Parks Playing fields and play areas Garden Amenity green space and private gardens. Municipal Plaza	Urban Parks (Azadi Park) Playing fields and play areas Neighborhood Garden Amenity green space and private gardens. Sara Plaza

C. Davies et al defined GI as "physical environment within and between our cities, towns and villages. It is a network of multi-functional open spaces, including formal parks, gardens, woodlands, green corridors, waterways, street trees and open countryside. It comprises all environmental resources, and thus a GI approach also contributes towards sustainable resource management". [230]

6.3.2 Green Infrastructure Typology at Landscape Scale

At a landscape scale of the metropolitan area, some important and challenging issue that have a very important impact on natural system in general and local climate and environment of the city in particular is analyzed.

The dominant features of CSC are the mountains to the N and NE which act as a backdrop, while at many vantage points there are views over the Tanjero valley to the opposing mountains. The main wadi or Sarchnar and Chaq-chaq valley, through which the Qlyasan River is permanently flowing with is riparian zone around, is forming an important landscape feature of the city. The foothills, due to its climatic improving impact of the City basin and is regarded as natural potential for successful afforestation areas, and the riparian zone (wadi) along it, and its limited climate improving impact at day time. As well as the large wadis with permanent water flow, a large natural tree, and shrub areas (especially southern airport area) are dominant. See Figure 6.4 illustrate the important typology at a landscape scale of CSC.

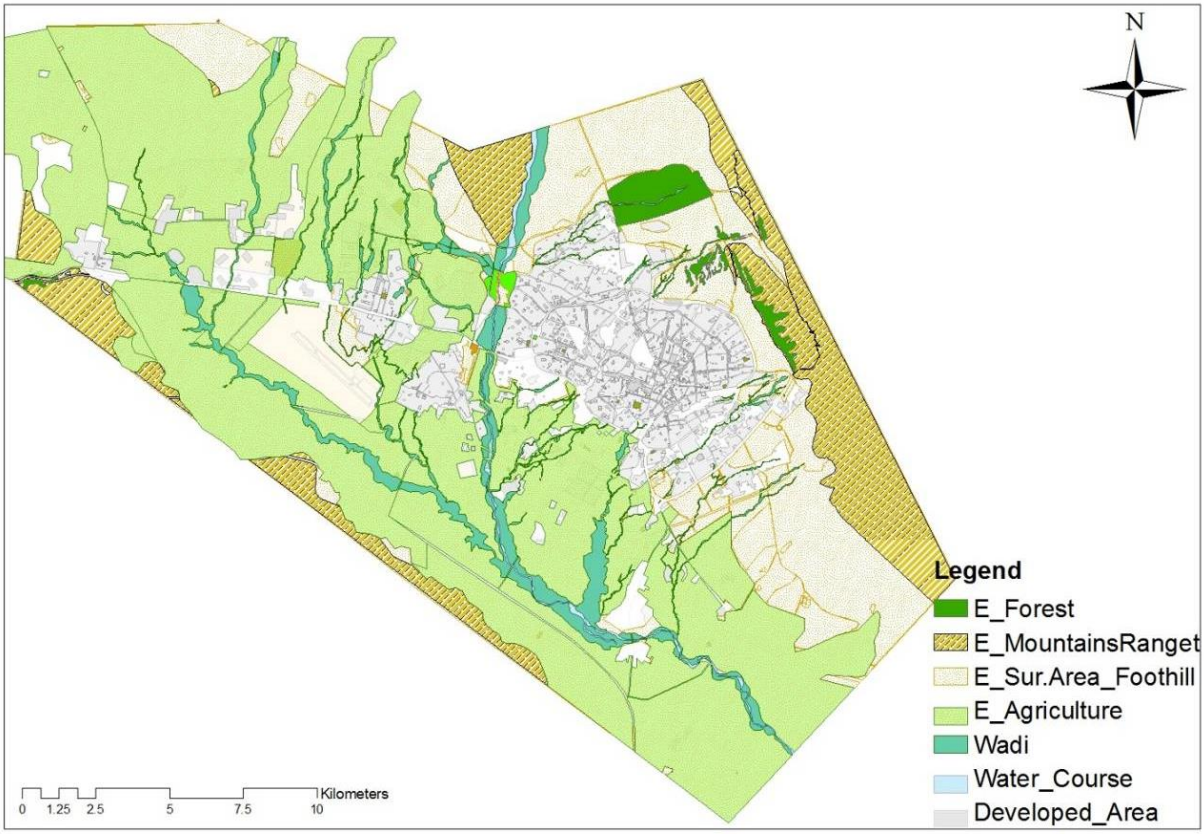


Figure 6.4: Key GI baseline map in CSC at landscape scale

Source: Author, 2010.

[230] Davies, C., MacFarlane, R., McGloin, C. & Roe, M. (2008) *Green Infrastructure Planning Guide*, *Version 1.1*.

Those features, from the ecological and environmental point of view, are of tremendous importance form landscape planning point of view. That is why from landscape and climatic degree of importance the GI typologies have been classified according to their degree of important, see Figure 6.5.

It is worth to mention that the Main Wadi development are undergoing as a tourism area lead into the Chaq-chaq area connecting to the Aztar zone, where tourist attractions, fun park etc., are being offered, to the main mountain range, dominating the skyline of Sulaimaniyah.

In this regard, the local down-slope winds from the Goizha Mountain have come to be increasingly important due to the city's distinctive overheating and cumulative and vertical growth.

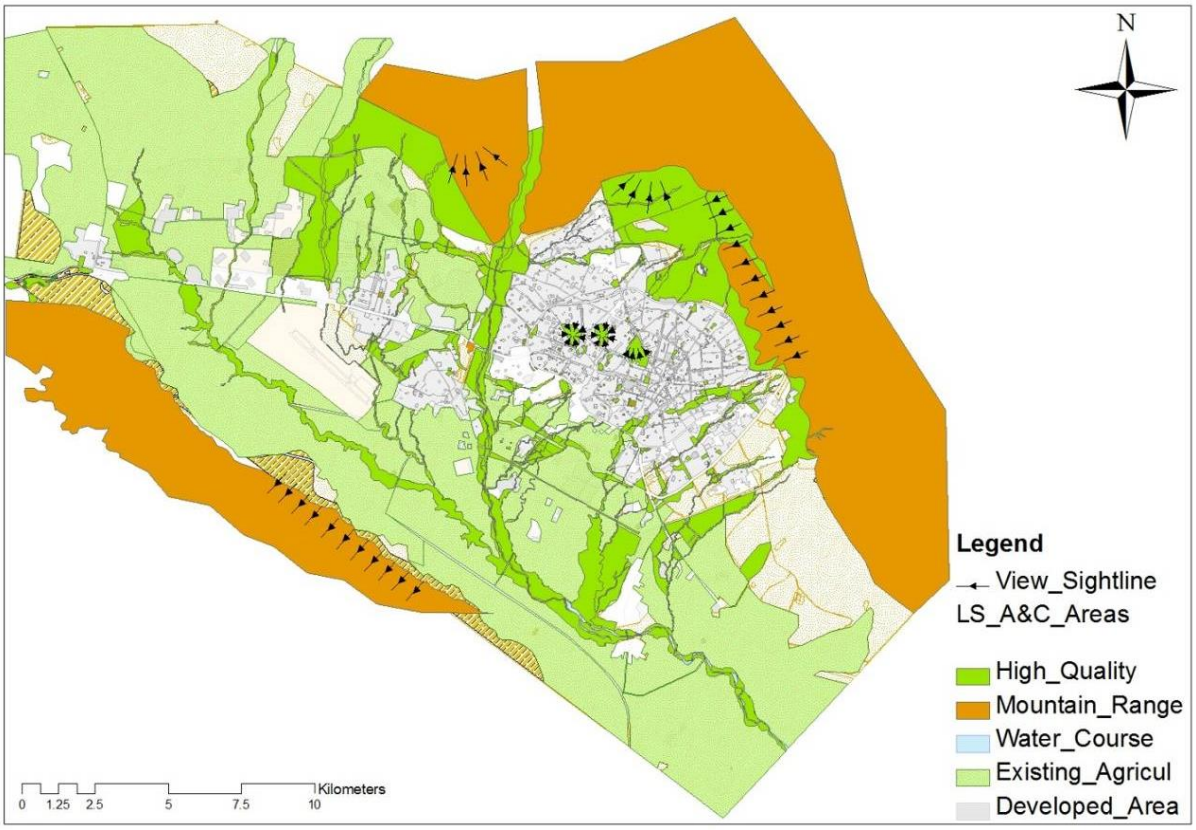


Figure 6.5: Landscape aesthetics and climatic areas in CSC

Source: Author, 2010.

6.3.3 Green Infrastructure Typology at Urban Scale

Urban Green Space are providing vital and multifunctional ecosystem services in the human dominated landscape, therefore the main focus in this part will be build up area that characterized by a dense urban pattern. In order to establish baseline for identifying the quantity and quality of existing GI and the Land cover type, due to unavailability of data the author adopted bottom up approach starting from the neighborhood level, to identify both the public green space quantity.

To pursue the analysis of existing GI in the urban area it is so important to map the different GI typology; therefore, the author adopted GI Mapping principal that has been illustrated in section

3.2.3.4. To give a general overview, in addition to the typologies mentioned at landscape scale, Urban GI typology consists mainly of city parks, neighborhood gardens, street tress, urban forest, and recreational areas. See Figure 6.6 that illustrate Key GI map in the urban area and its surrounding of the CSC.

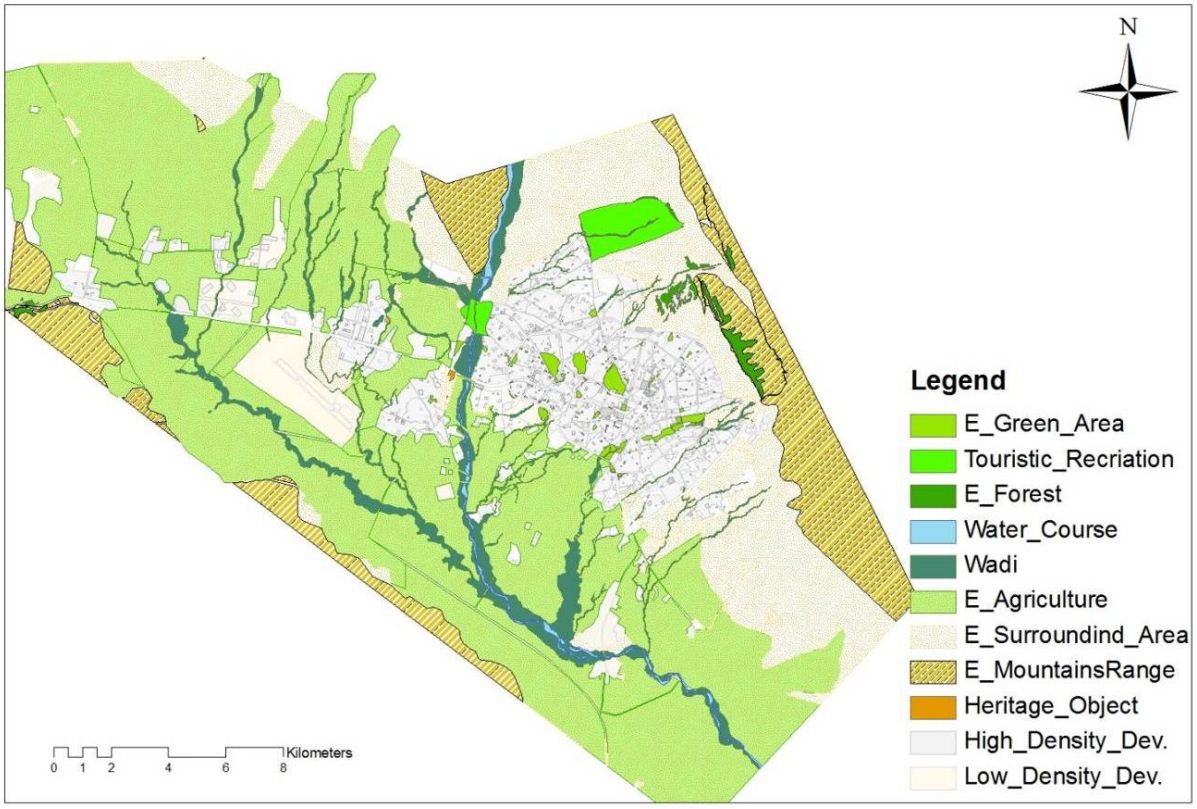


Figure 6.6: Key GI baseline map in CSC

Source: Author, 2010.

6.3.3.1 Quantity

There are different approaches to quantify GI quantity. In the CSC (within municipality boundary as shown in Figure 6.6 the overall share of GI without agricultural typology is estimated as 8%. In addition, the distribution share of existing GI typologies is derived after the analysis of the land use of CSC, see Figure 6.7. It is worth to mention that agricultural land and arable land in the surrounding area have not been taken into accounts.

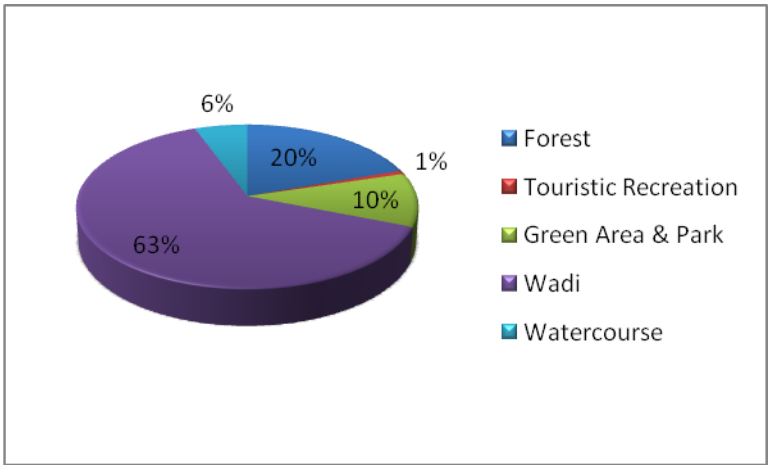


Figure 6.7: Existing distribution share of GI typology in CSC

Source: Author, 2010.

The overall percentage of existing Green Area and Parks in the CSC within Municipality boundary is estimated by 0.08%. While in the main built up area in the E part of Qlyasan River without the surrounding open typology (see Figure 6.8), contains approximately 5.25% of GI including the planned gardens of the existing areas.

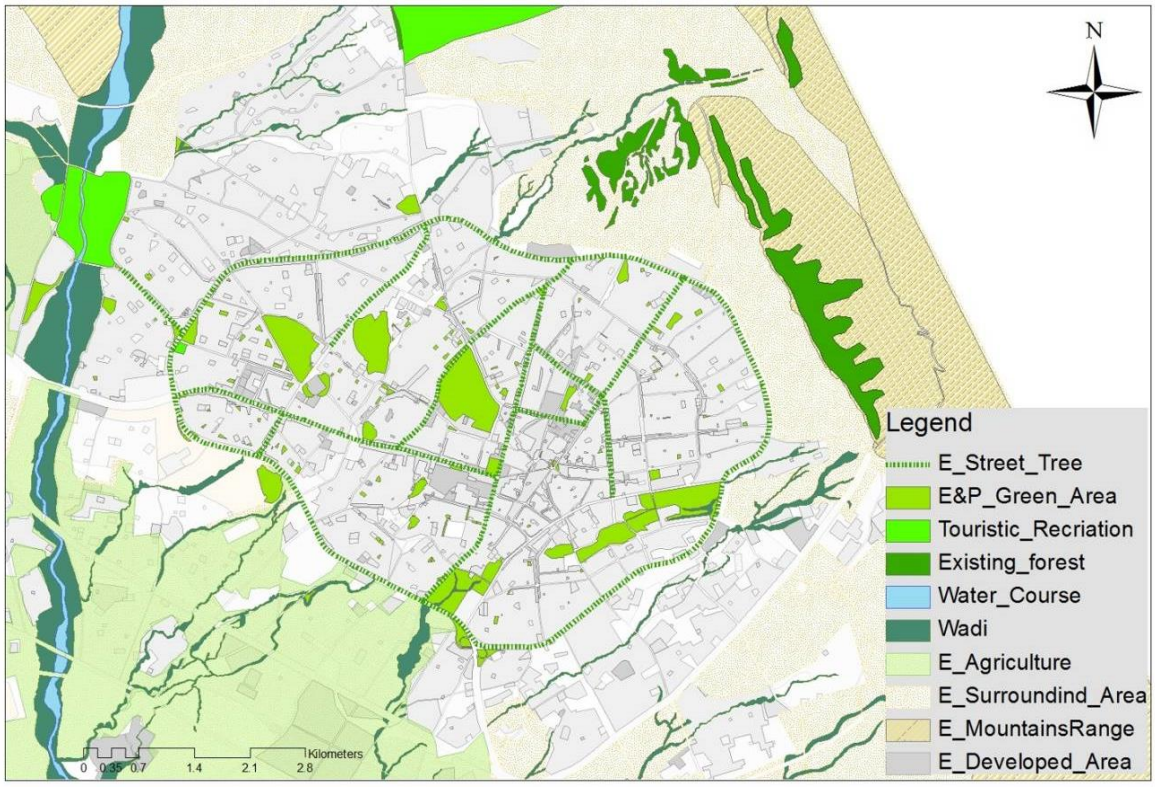


Figure 6.8: GI typology in the main build up area.

Source: Author, 2010.

Another approach in quantifying green space is to relate it to population density, by calculating population share of green space. Adopting the bottom-up approach for analysis, the green space quantity in relation to population density at the neighborhood and existing city build up area are

calculated. At the city level green area share is about 3.5 m^2/capita, while at the neighborhood level the share of green space is ranging from 0.01 to 92 m^2/capita. That is why author (deriving from the municipal division) divided the area into eleven main sections to have better representation of green share per capita. For the section share of green space is ranging from 0.0 to 9.85 m^2/capita see Table 6.2 with the corresponding Figure 6.9. It is worth to mention that this share doesn't include tourist area, wadi and cemeteries The share is differing according to the historical development stage of the city, but nevertheless can be regarded as a violation of social equity in terms of planning concepts.

Table 6.2: Share of green space (m^2 /capita) and population density in CSC

Source: Author, 2010.

Section No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
m^2/ Capita	8.7	6.4	9.4	0.7	4.25	9.85	1.93	6.19	2.32	0	3.14
Pop Density	116	141	125	204	164	101	156	111	72	66	117

From the analysis result, it is clear that in term of quality regardless of the approach of quantifying green area, there is a lack of green area in built up area. The minimum slandered by Time Saver is 10.2 m^2/capita, by this order all the section under study failing under minimum standard, in other words increasing green is necessary at all part with different range. As a conclusion section 4, 5, 7, and 11 can be regarded as a hot spot, and identified as priority area for mitigation. While Section 9 and 10, since both spatially are near to touristic area and new afforestation area can be regarded as a second set of enhancing green inside the neighborhood.

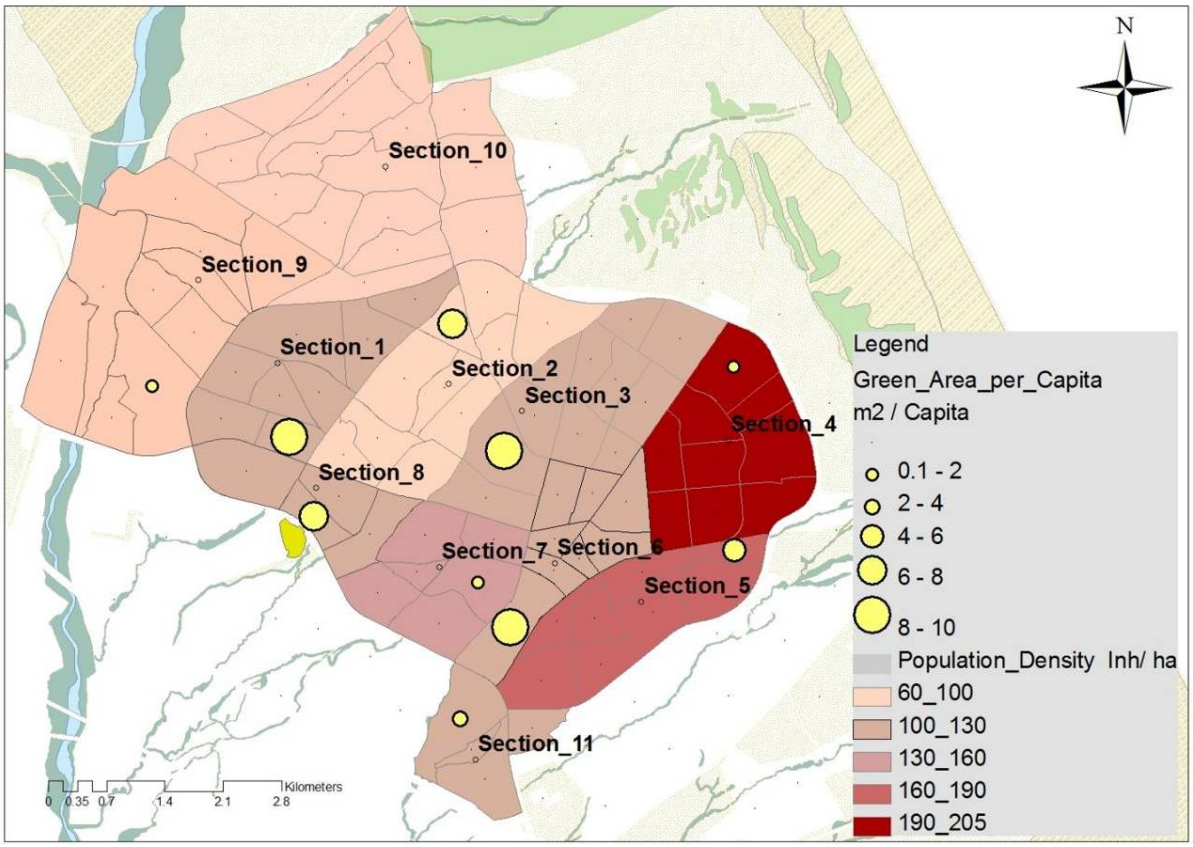


Figure 6.9: Share of Green Space Per Capita at Section Level.

Source: Author, 2010.

6.3.3.2 Quality

Quality can be dealt with according to the different aspect. The quality of green spaces and links can be "determined by the concepts of sufficiency and suitability"[231]. The former can be determined by identifying quantity according to set of suitable standard while the latter (suitability) consist of analysis of the needs of the surrounding area. In this regard, for the course of this investigation the functionality and sufficiency are formulating the base of the analysis.

Since both main city parks, located in the heart of build up area in terms of functionality, can be regarded as oversaturated considering their size, particularly in spring and summer providing a high recreational services. Regarding climatic engineering performance, they have a cooling effect; generate good infiltration capacity as well as oxygen producing open area, so contributing actively in improving city's microclimate.

The green hills and cemeteries are natural landscape features in and around the city that have provided a vivid scenic view in and around the city. Green hills, due to the dense plantation they provide a good climatic performance as regulating temperature and carbon sequestration capacity and to lesser extent the decrease of surface runoff. Although with their high ecological performance their social function in recreational sense are so limited.

However the neighborhood gardens are small in size, but this category are actively functional in terms of use, since they have been spreader in the neighborhoods that have been planted and mostly consist of large lawn areas, some decorative shrubs and very few trees. In terms of planning they would be categorize as leftover plots and sometimes well planned this differ from one neighborhood to another according to the historical phase of development of the CSC. Regarding climatic engineering performance, due to their size it cannot be regarded as highly performing quality in this sense. Generally, the street tress can be categorized as under good quality with continues management by Sulaimani Municipality, Which has a positive contribution by providing shade in the summer and to some extent removing and filtering air pollutants. To establish a visual understanding of different GI typology in the CSC, see Figure 6.10.

[231] Davies, C., MacFarlane, R., McGloin, C. & Roe, M. (2008) *Green Infrastructure Planning Guide*, *Version 1.1*.

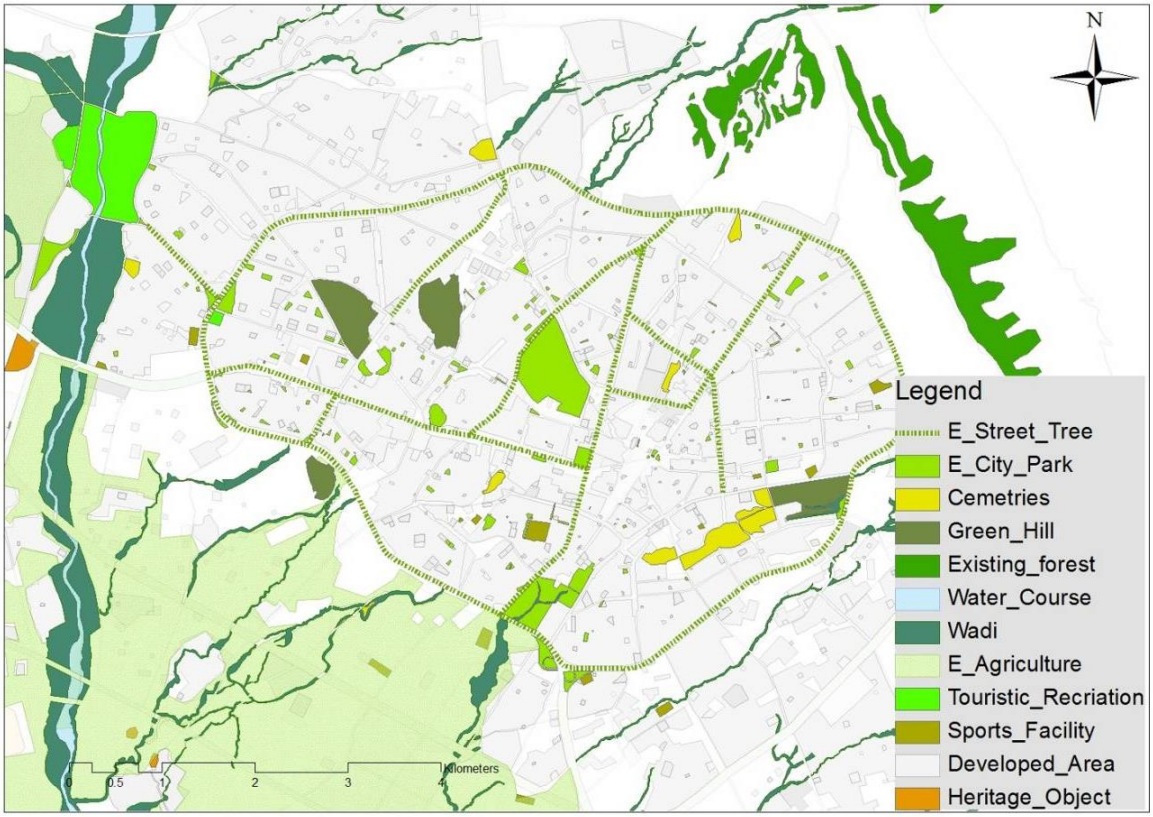


Figure 6.10: GI typology baseline map in CSC

Source: Author, 2010.

Considering sufficiency by applying GI principal the green area is it be natural or manmade must be classified according to their size. Consequently, few categories can be classified. Within the city itself, only few large-scale green areas are to be found 'City Parks'. The main recreational parks that are considerable in size are 'Azadi Park, Public Garden and Piramerd park' the latter is at planning face. One more important category is the hills inside and around the city, a number of which planted with evergreen tress with considerable size and density (high vegetation index). The cemeteries also falls within this category but with less vegetation index.

Street trees are other assets Major roads and selected neighborhood access roads are furnished with street trees that are approximately estimated as 50000 trees, with small ornamental gardens at the road layouts. One controversial typology is neighborhood green space or neighborhood gardens that must be filtered out considering quantity classification since they are small in size would be categorize as leftover plots, although they are actively functional. Meanwhile a portion of the existing parks seem to be leftover plots resulting out of the existing plot and road layouts and are firstly too small to be mentioned as a park and secondly located in roads, cloverleaf's. Their function can be limited to the ornamental purpose.

In order to establish spatial understanding of deficiency areas in terms of accessibility of existing green space and to establish a visual idea about where is green needed the buffer analysis has been carried out. Figure 6.11 to Figure 6.15 illustrate the effect of different sized thresholds being applied in the assessment of green space provision. The first set of analysis including only area inside 60m ring road. It is obvious that there is lack in term of quantity and accessibility, since as it has been shown in Figure 6.12, more than 63% is not covered according to 300 m threshold.

While considering GI concept all the GI even blue typology (watercourse) should be included as well. Accordingly in the dense part of CSC (inside 60m ring road), clearly, the 10 ha threshold, give more complete coverage appears in the resulting maps. Considering 30 ha threshold it is obvious that the S and E part of the CSC has a clear shortage of large natural green areas. However, different sized thresholds are appropriate for different purposes and scales of analysis; in this part, GI is primarily considered urban level.

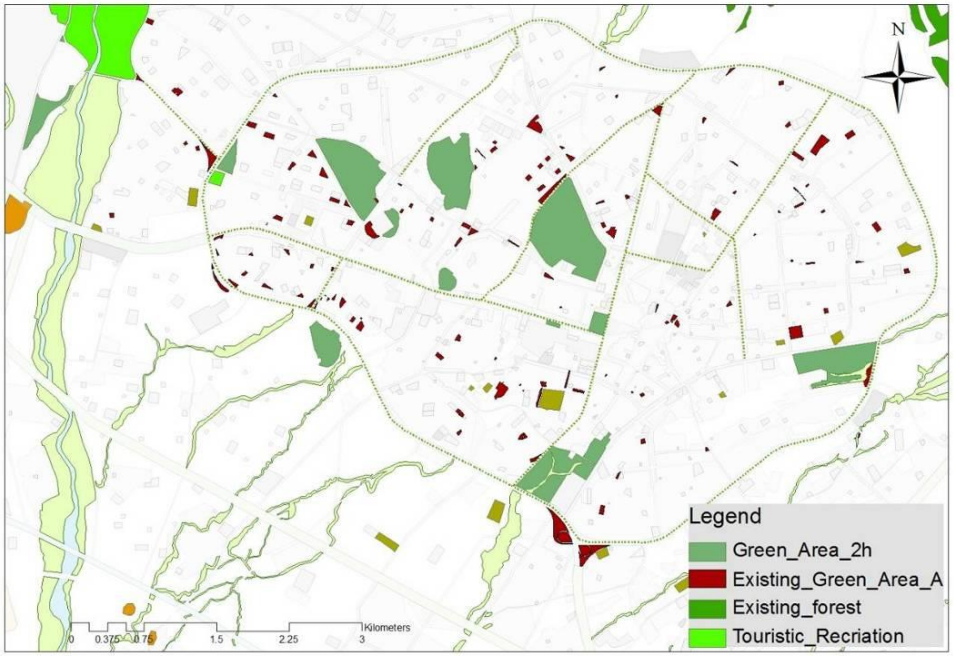


Figure 6.11: Green spaces greater than 2 ha inside 60m ring road area.

Source: Author, 2010.

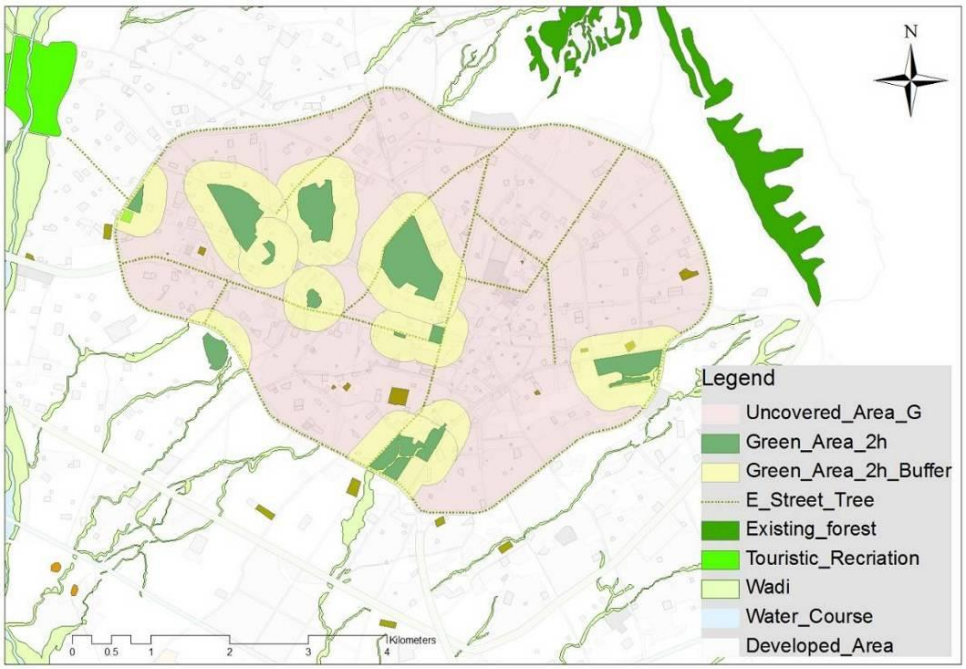


Figure 6.12: Green spaces greater than 2 ha with 300 m buffer applied inside 60m ring road area.

Source: Author, 2010.

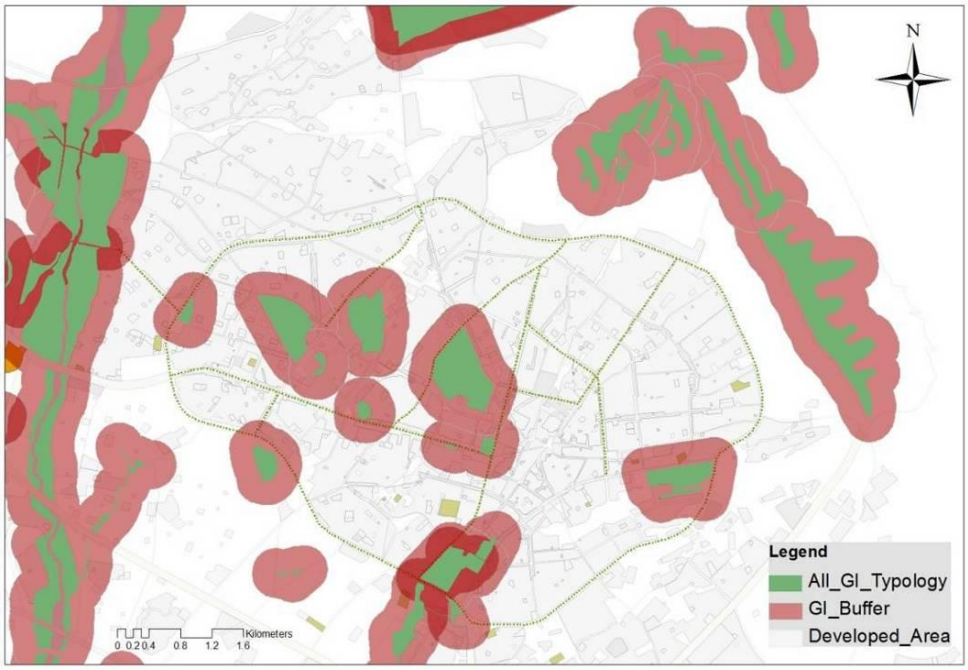


Figure 6.13: Green spaces greater than 2 ha with 300 m buffer applied in CSC

Source: Author, 2010.

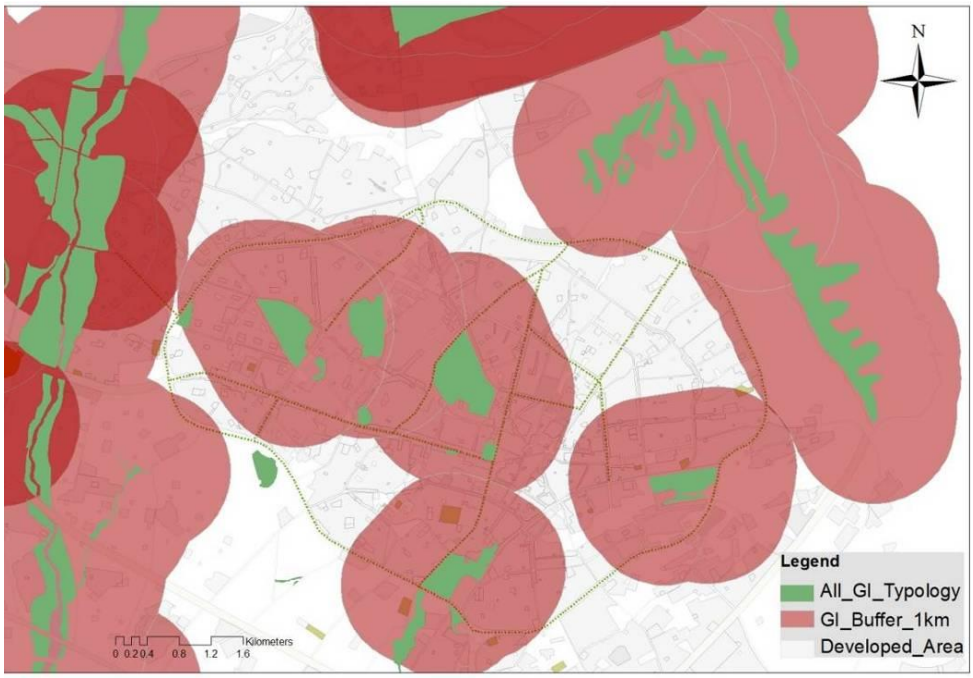


Figure 6.14: Green spaces greater than 10 ha with a buffer of 1 km applied

Source: Author, 2010.

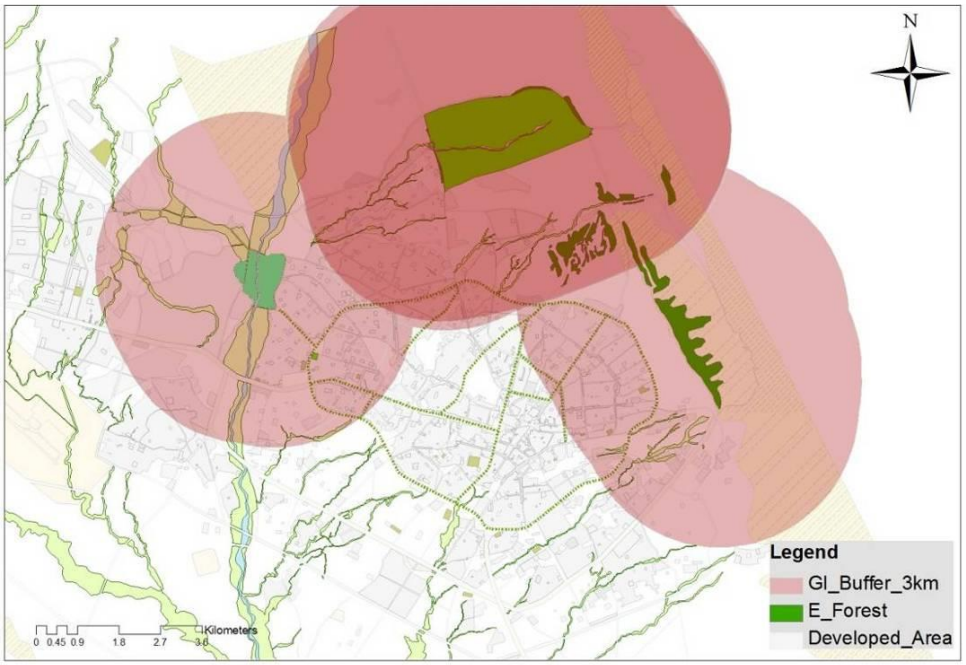


Figure 6.15: Green spaces greater than 30 ha with a buffer of 3 km applied

Source: Author, 2010.

From buffer analysis for the whole area in E part of the Wadi it is estimated that around 65%, 44% and 43% is uncovered according to the GI standard for 2, 10 and 30 ha threshold correspondingly. For the development outside this area, all the patches are having a clear deficiency regarding all threshold standards. It can be concluded that within the hart of built up area obvious shortage is observed. After intersecting the uncovered area by applying different thresholds priority areas for action identified, see Figure 6.16.

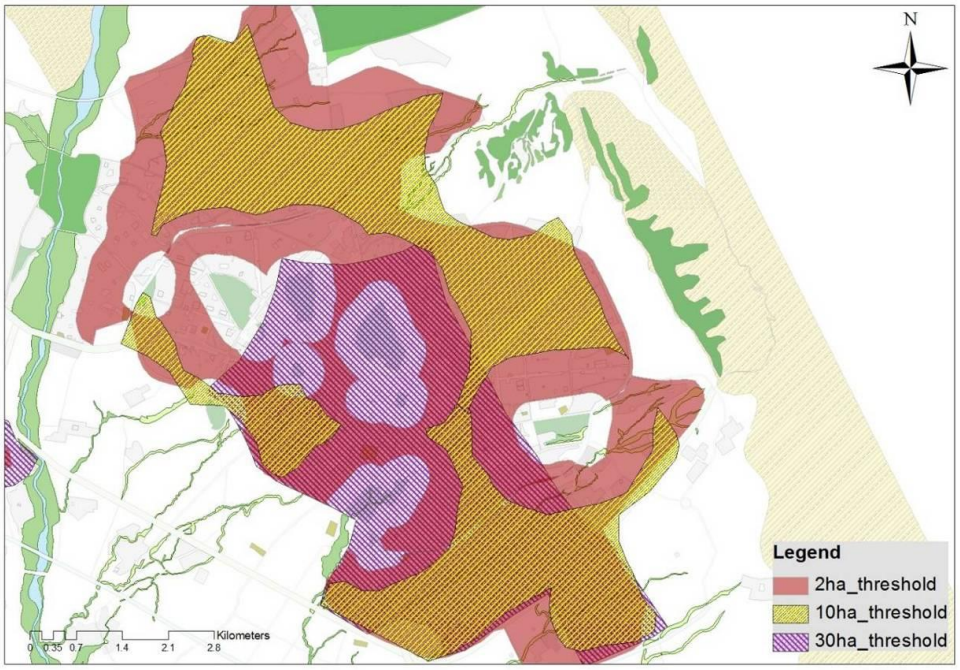


Figure 6.16: Buffer analysis overlay for applied different threshold

Source: Author, 2010.

Population density together with accessibility coverage is giving a key indication to answer “where is necessary to add green”, that is why key GI typology had been presented against the existing population density to give spatial immersion about deficiency areas in existing built up part. In addition, another important dimension that has to be integrated is the area of new developments, since it is affecting the new Green Concept that will be developed for the CSC. These represented in outskirts areas with population density ranging from 0 to 30 inhabitants /ha, see Figure 6.17.

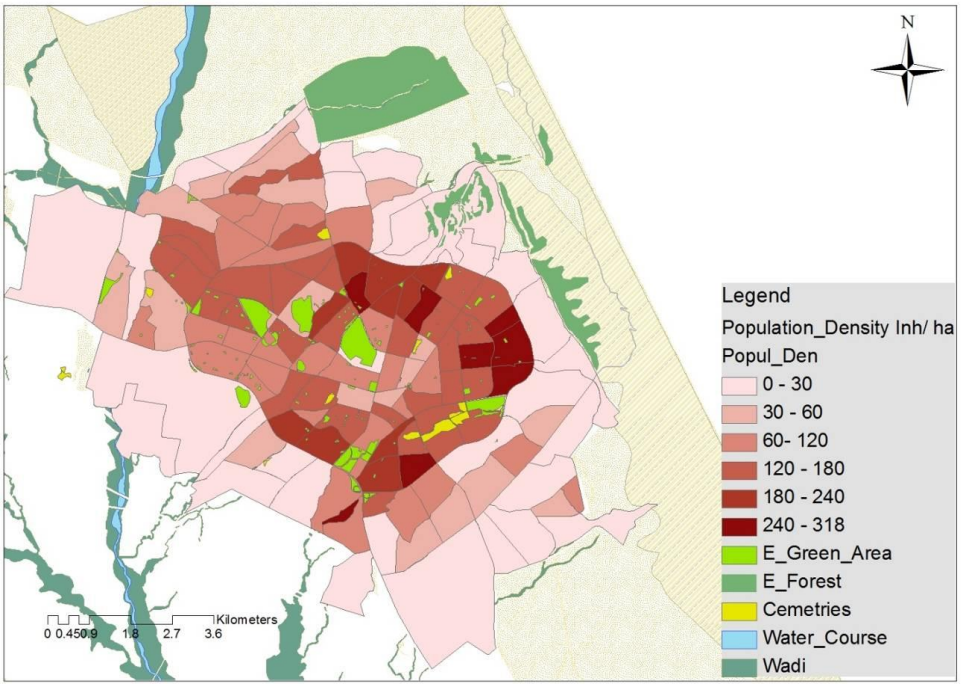


Figure 6.17: Key GI typology overlain on population density data.

Source: Author, 2010.

Accordingly, to show the area of deficiency, that is necessary to put into action zone, see Figure 6.18, that illustrates propriety area that has to be taken into consideration in term of quality and sufficiency perspective.

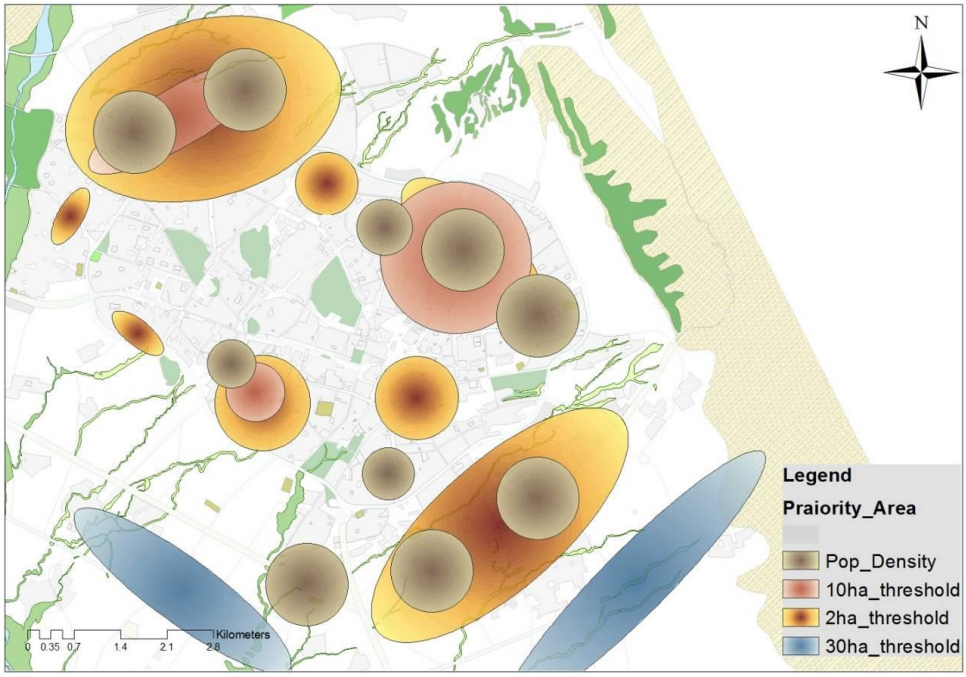


Figure 6.18: Map of priority area based on quantity and quality analysis

Source: Author, 2010.

6.3.3.3 Connectivity

Connectivity is giving the dynamic to the green network; it will enhance its environmental, social and economical ecosystem functions. In order to establish a spatial understanding of the physical gap and to have a clear vision of what to link, this part is covering both the existing and planned green areas in order to maximize the benefits, increase feasibility and apply the concept of integrity in planning.

In the CSC, there is no considerable connection in between the City's green areas like greenway or blue way. Some few parts are connected through street trees (e.g. Azadi Park to the open land around the city).

The urban green space consists of the branch of small isolated green patches that have no connection neither in-between them inside the city nor between them and open landscape outside the city that shows existing links and missing links. Most importantly within this dense and compact urban pattern is the absence of green or open corridor particularly 'natural wind travel route' that will enhance the air flow through the city that minimize the exchange of air especially in summertime.

The newly overdevelopment of hillsides with high-rise building, caused thermal pollution because of dense development and inadequate catchment zones entailing of undeveloped and unsealed surfaces, moreover, blocking the cool air downward flow from the hillside that act like lungs for the city particularly in summertime.

In order to develop a visual understanding for the reader see Figure 6.19 that illustrates the physical analysis of the GI.

6.3.4 Planned Green Areas

Tourism Master plan shows those areas interconnected as an clasping belt in the N and W direction of the CSC, depending on a provision that in the future the CSC city will develop and fill the existing gap, eventually it will act as a green arch for the city. This provision of city development to some extent does not mach to the growth and development direction by the new Master Plan.

The physical gape for the Tourism Master plan can be concluded by lake of green connection to existing build up area, even if it is based on different development vision for the city, see Figure 6.19. Over development of Sarchnar and Chaq-chaq area have a negative impact from a landscape and biodiversity viewpoint, by introducing a lot of hard surface and converting the existing green to mass of concert. Sarchnar valley was totally open 20 years ago, but now it is totally enclosed by building and the green valley has completely lost its scenic and visual values.

Finally, dense development of transportation network (sky train, including an accompanying maintenance road, all along the “tourist belt”), works diversely with biodiversity concept and will present a major impact on the environment. Nevertheless, this should be investigated against the feasibility of touristic plan and recreation and income that will be created after implementing the project.

It is worth mentioning that the Tourism Master Plan adopted GIP concept in introducing Wind Park that can be regarded not only as implementation of basic concept of GIP but also the concept of sustainable development by introducing renewable energy. Investigation and study of economical and technical aspects are sufficiently proving the valuation of suitability of a wind park of a certain size to be located in this area, should be carried out.

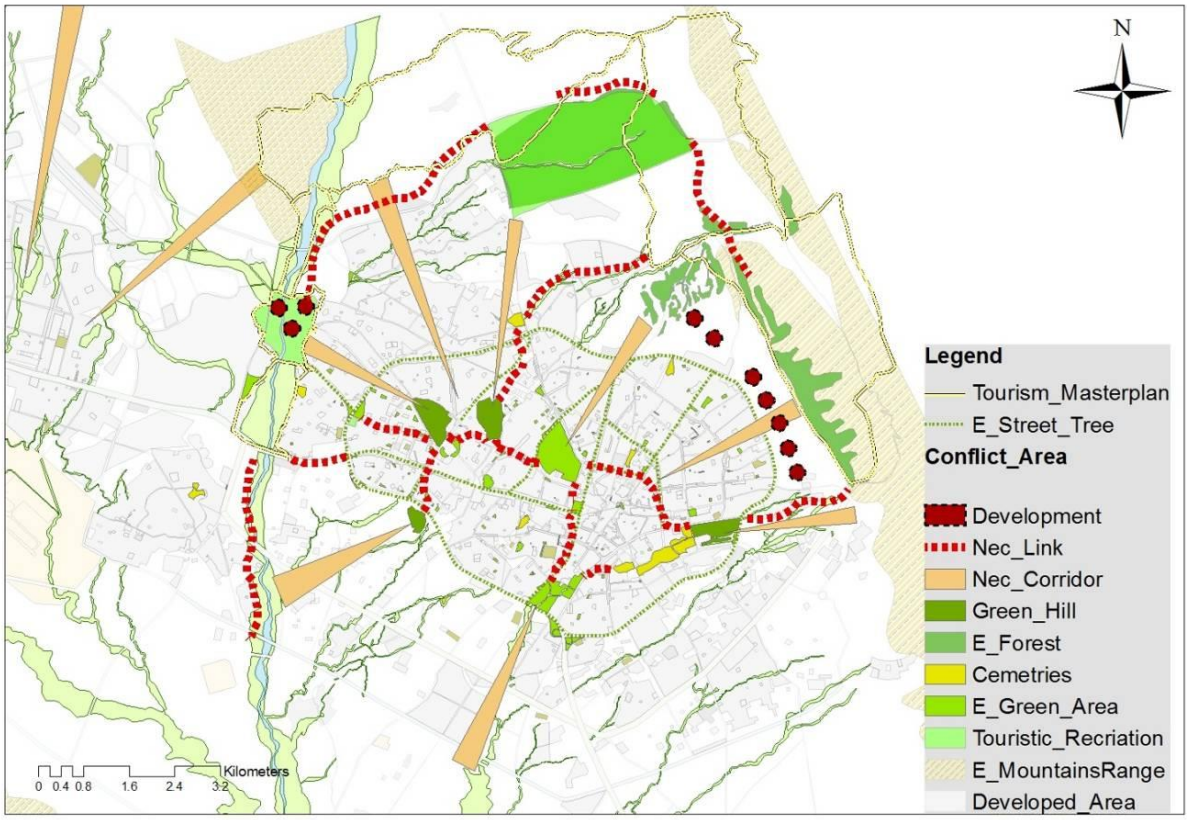


Figure 6.19: The physical gape analysis between existing and planned key GI component in CSC

Source: Author, 2010.

6.3.5 Institutional Analysis

The lack of integrated planning even at the local Municipal level is one of the basic institutional gap and challenges in the CSC including all domains. Also The lack of join forth policy. Different plan by different interested part like Tourism Master plan, Green parks inside city by municipality and reforestation by Ministry of Agriculture. All these have not been integrated in between different institutional authorities.

The vivid example is the exclusion of the Tourism Master plan in Sulaimaniyah Master Plan, although the Tourism Master plan is finished in 2006 that make logic to be integrated in the new Sulaimani Master Plan of the CSC since it finished in 2009. But the only integration is about Sarchnar Area, since it is an existing important green area acting as a pole of recreation for the city since founding Sulaimaniyah city.

The Sulaimaniyah Aquifer Problem sourced mainly from unsustainable management of water resource in Sulaimaniyah Sub-basin outcrops and particularly in the CSC and lack of strategic planning by KRG. This can be concluded in two main challenges.

The drastic decline (drying up) of Karez within few years in the CSC, due to the over pumping of aquifer which is a strong indication of unsustainable use of ground water resource. Also the lack of strategic planning to get use of the plenty surface water resource instead a dependence of ground water. This is an indication of KRG's faller to cope with development and growth in time and incapability to provide fundamental services in a sustainable way.

In addition, the Sulaimaniyah Sub-basin is about 36.5% of the whole sub-basin of Sirwan River, with a good condition for a high rate of infiltration. With the urban growth and increased rate of soil capping with impervious surface the area Sulaimaniyah Sub-basin will decrease by 20%. This will affect the ground water discharge capacity as well as it will increase the runoff amount in wet season with high precipitation rate. This also indicates again the lake of sustainable management and adaptation strategy in a new developed area.

6.4 Identifying focused ecosystem services

The core strategy concept at metropolitan level is City Climate Engineering Benefits and connectivity. That is why the ecosystem services adopted as a base for GI plan development are focused on Climate Engineering Benefits which include 'managing high temperatures, managing hydrology particularly surface runoff, Carbon storage and sequestration and air quality management', see Figure 6.20.

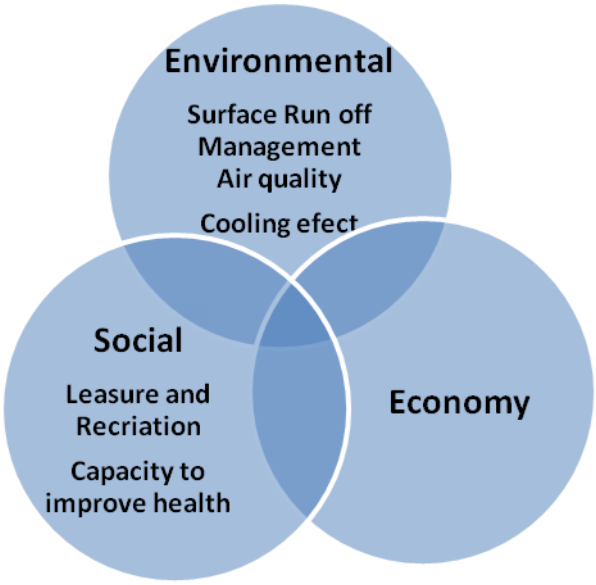


Figure 6.20: Main ecosystem services at metropolitan level

Source: Author, 2010.

In order to illustrate the direct effect of percentage of green area or in other words 'Normalized Difference Vegetation Index (NDVI)'to climatic situation and ecological performance of the urban area, the author adopted similar concept to Whitford, V. et al, by establishing ecological performance for the existing situation. In the course of this paper, one of the ecological indicators (biodiversity indicator) has been sorted out due to the lack of data.

6.4.1 Temperature Management

"More deleterious effects of urbanization on climate occur during the summer months and result from changes in the energy exchange processes." [232]

[232] Whitfort, V., Ennos, A.R. & Handley, J.F. (2001) *Landscape and urban planning: "City from and natural process" – indicators for the ecological performance of urban areas and their application to Mersevside.*

Since the climate of CSC is characterized by hot summer. Average monthly temperature in summer varies between 22-34 °C and the maximum mean average monthly temperature is recorded as 33.5 °C in July in last 10 years. Therefore, the effect of urbanization on climatic engineering characteristic is more serious, for adaptation strategy this should take that in to consideration.

The temperature map created by adopting two different methods , the first set based totally on the surface temperature according to surface material, that derived from the Normal (Gaussian) distribution function that adopted from Time Server Slandered. The maximum mean average monthly temperature in last 10 years is taken as a base air temperature for calculating the material temperature except for soil and grass that were taken from direct record of last 10 year in CSC. It is worth to mention that this map based on Land use map of 2007, see Figure 6.21 shows the land use and surface material cover. The analyses merely done on the base of surface material cover, without taking into consideration any cooling effect of natural vegetation, also the natural vegetation at the level of private lot has not been considered as well. Building mass has been taken in to account, e.g. Building more than 3 stories considered as Concrete plus due to more built up surface. See, Figure 6.22, illustrate temperature map of urban area and its surrounding.

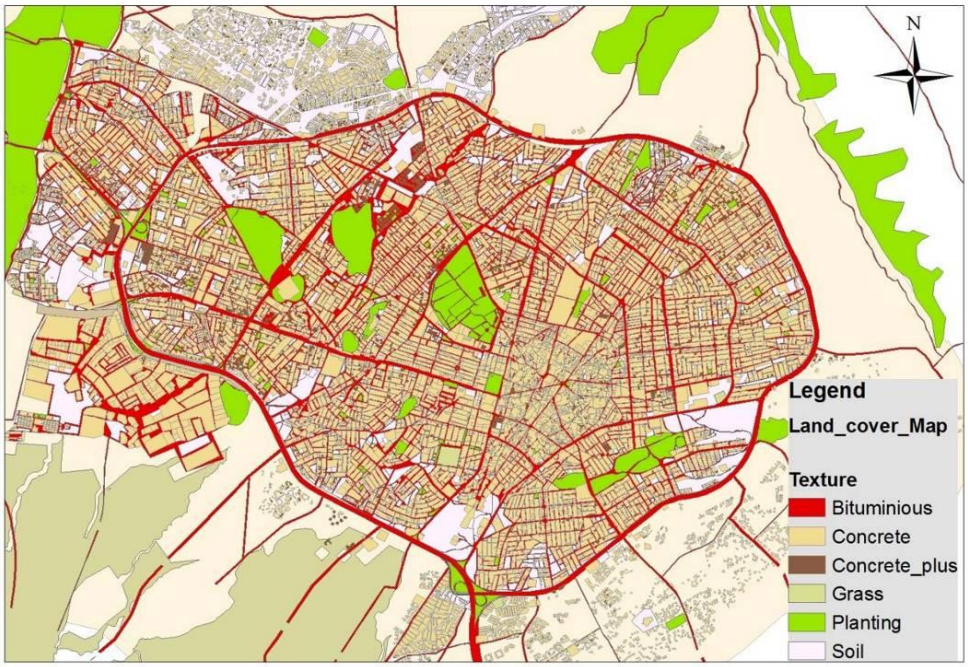


Figure 6.21: Map of surface material cover based on land use map 2007

Source: Author, 2010.

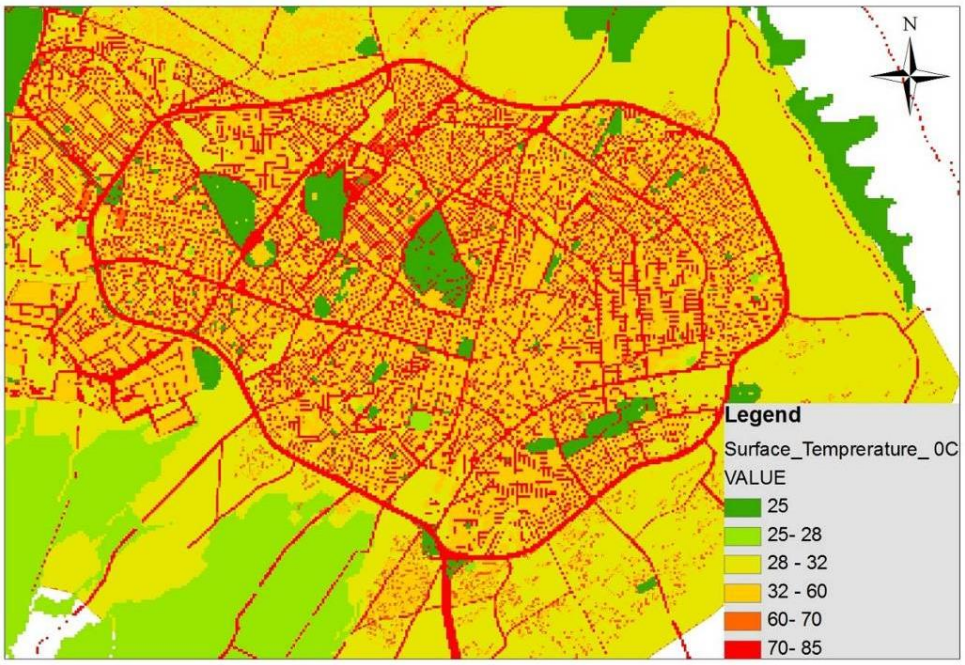


Figure 6.22: Surface Temperature map based on surface material cover in CSC

Source: Author, 2010.

The second method, which is more representative for the modeling of temperature mapping since it takes into account the climatic and vegetation effect, but it is also not free from error in the exact assumption of temperature. It has been adopted from research about "Remote Sensing Technique for Land Use and Surface Temperature Analysis for Baghdad, Iraq" [233] with applying correction factor according to the metrological state and land cover quality of the CSC. See Figure 6.23; illustrate the temperature map for the existing state of the CSC.

Surface temperature or surface UHI can be derived as a function of surface cover admittance properties, land-cover sorting and land use patterns. At a local setting, the commercial and the dense residential zones were confirmed to produce higher surface UHI with lowest vegetation index. The spatial coherence of surface temperature dissemination was associated with the morphologic setting of urban development. It is worth to mention that this model took the assumption that new developed area will be filled with the same pattern.

[233] Saleh, S.A.H. (2003) *Remote Sensing Technique for Land Use and Surface Temperature Analysis for Baghdad, Iraq.* University of Al-Nahrain-Iraq, http://www.gorssy.net/conferences/files/e/Dr.%20Salah%20Saleh.pdf

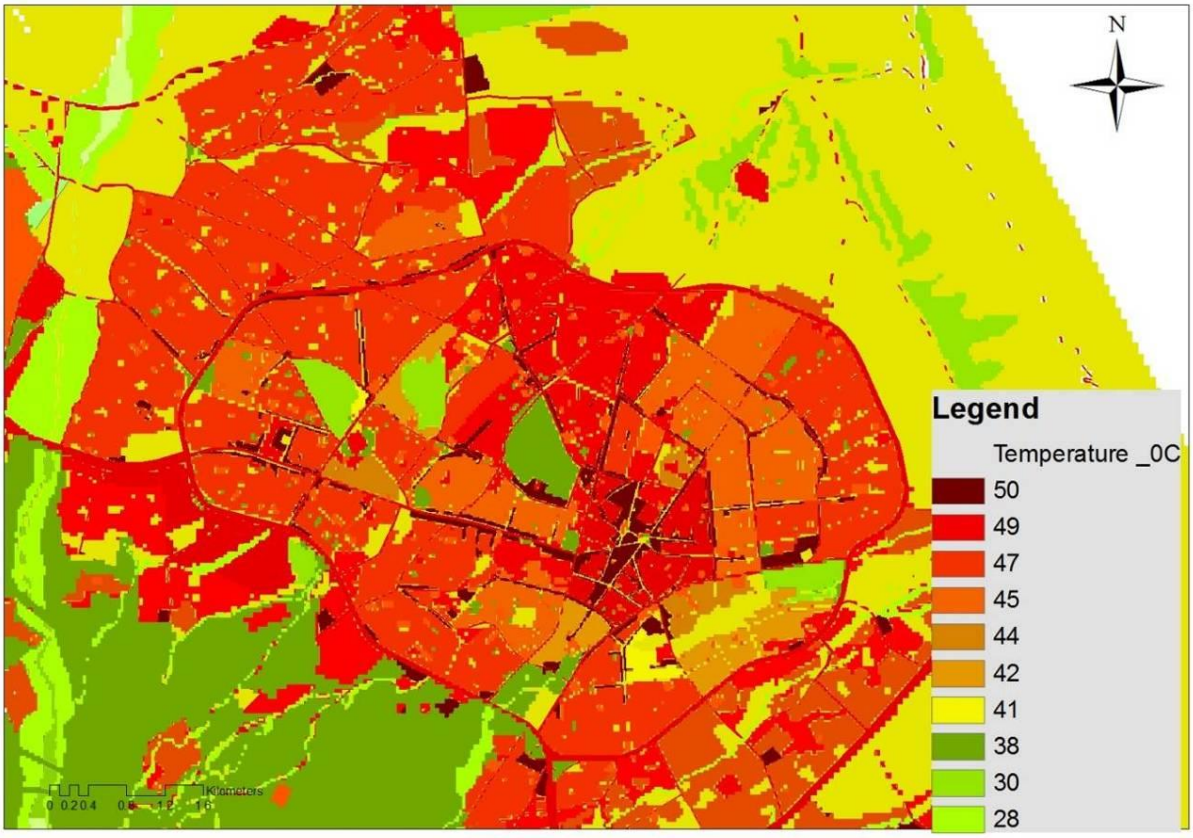


Figure 6.23: Existing Surface Temperature map corresponding to vegetation cover ratio in CSC

Source: Author, 2010.

6.4.2 Hydrology management

In order to characterize the urban environment and quantify the effect of green cover it is essential to know distribution percentage of green cover over the urban area. The map of proportion and distribution of pervious surface has been developed on the base of classifying certain urban morphology categories. See Figure 6.24 that illustrates the over capping in the urban area particularly the development stage after 1990s and city center.

For applying the hydrology model, the CN, (curve No. of particular type of watershed) of the area under investigation slightly differ around the buildup which area 78 and 81 in N and S correspondingly. So the amount of runoff calculation basically will be a function of proportion of pervious and imperious area and amount of precipitation, with assuming the same infiltration capacity for all pervious area. That is why the delay and decrease of runoff is directly proportional with green area percent.

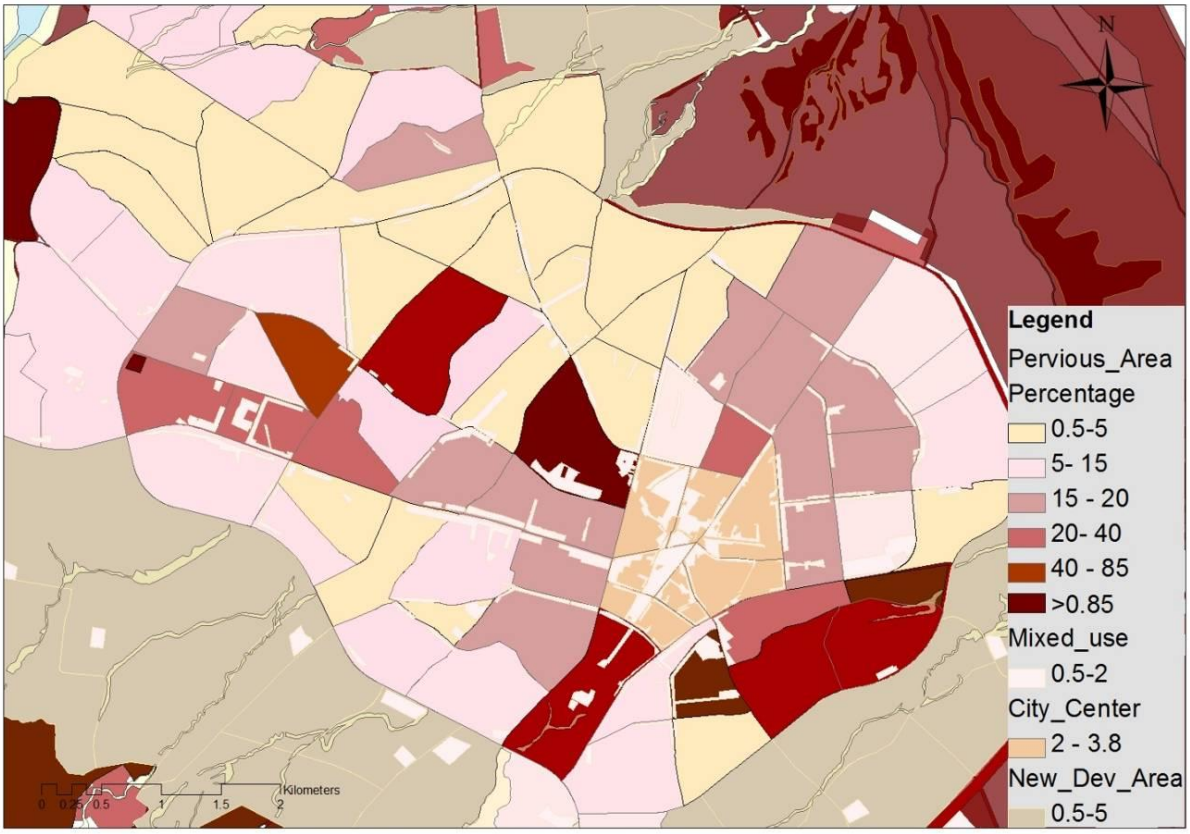


Figure 6.24: Existing proportion of evapotranspiring surfaces urban morphology sampling in CSC

Source: Author, 2010.

6.4.3 Carbon storage and sequestration

Green areas are of great importance to the hygiene of a city as oxygen producing spaces, although this function is quite important but it is limited as well when it comes to urban green due to the area of tree cover. Since there is no data about this layer the author set an assumption based on the GI typology: forest and urban greens regarding 80% and 40% as tree cover correspondingly. The total area covered by tree is roughly estimated as 925 ha. Appling Whitford, V. et al Carbon storage model at a neighborhood scale, the result shows no neighborhood fallen within the good limit 0.13 tonnes ha^{-1} except for forest are and green area particularly green hills. See Figure 6.25 that illustrate tree cover percent and carbon storage capacity at a neighborhood level.

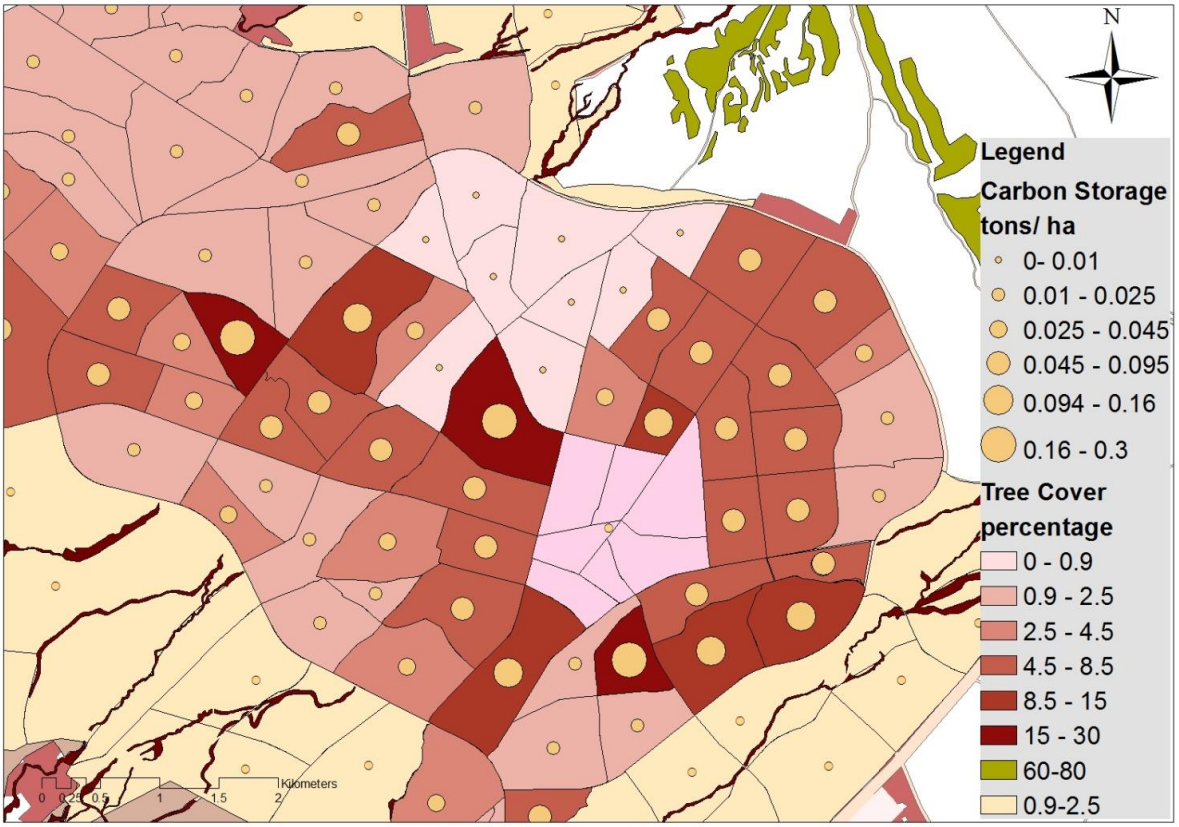


Figure 6.25: Existing proportion of tree cover percent and carbon storage capacity in CSC

Source: Author, 2010.

6.4.4 Air Quality

The polluted and warmed-up climate in the built-up city core is relieved by the cooler and regularly fresh cold-air currents from the higher and undeveloped terrains, in which the topographic locality enables the cooling process formation.

However, this is diverse on weekends, when crowds of people are fleeing the city to the E into the cooler mountains to find relief of the unbearable climatic situation within the city in summer. Consequently, the only road to the E ascending the mountains is overused and traffic jam occurs. This has a very negative impact on air quality of the city. Since at night, cold air flows downhill, settling into lowland zones (basins and valleys). This cool air is heavily polluted with the vehicular pollutants drains and settles in the CSC. The cool air sinks and accumulates in these city's basin and valleys, trapping air pollutants.

In order to give an over view about the rate and range of emission that caused from automotive activity, the author depended the use of MlusEeg software (PC-calculation method of Practice in 2002, as amended, 2005, version 6.0f). Certain important routs have been elected for this purpose according to degree of use and possibility for mitigation. The volume of traffic and trucks percentage based on the traffic survey by School of Town Planning Sulaimani Technical College, in-between 13th July to 31st July. The traffic volume must be The average volume over the year , but due to the limitation of data and the severity of pollutant effects at this time of the year this in a contain to the adaptation measures that is adopt from GIP point of view , taking this traffic count result will best fit

the purpose of the study. One more assumption has been mad, German case (JM-V, 98P-T) took for the base pollutant amount, see Table 6.3.

Table 6.3: Car Induced pollutants in major section in CSC.

Source: Author, 2010.

Component (µg/ m³)	CO	NO	NO2	NOx	Pb	SO2	Benzene	PM10
Preloading	1500	50,0	45	0	0.6	35	3.5	40
Additional load (JM-Z)	109,7	34,82	19.91	73.3	0	0.29	0.323	4.238
Total load	1610	84,8	64,9		0,600	35,3	3,82	44,24
Appraisal values	-	-	40,0	-	0.5	20	5	40,00

*Heavy truck 14 % (>3,5 t), average wind speed 1.8 m/s, Slope+/-2% and traffic volume 40000 car /h.

The emission calculation has been limited to car induced pollutants such as Nitrogen oxides NOx; PM10, Carbon Monoxide (CO), Benzene and Sulfur dioxide (SO_2) and, the pollutants that have a direct effect to human health. Herein below (Figure 6.26) the graphical representation for some pollutants of the left case is PM10 amount from designated traffic volume, while the right is the total pollutant after adding the base amount.

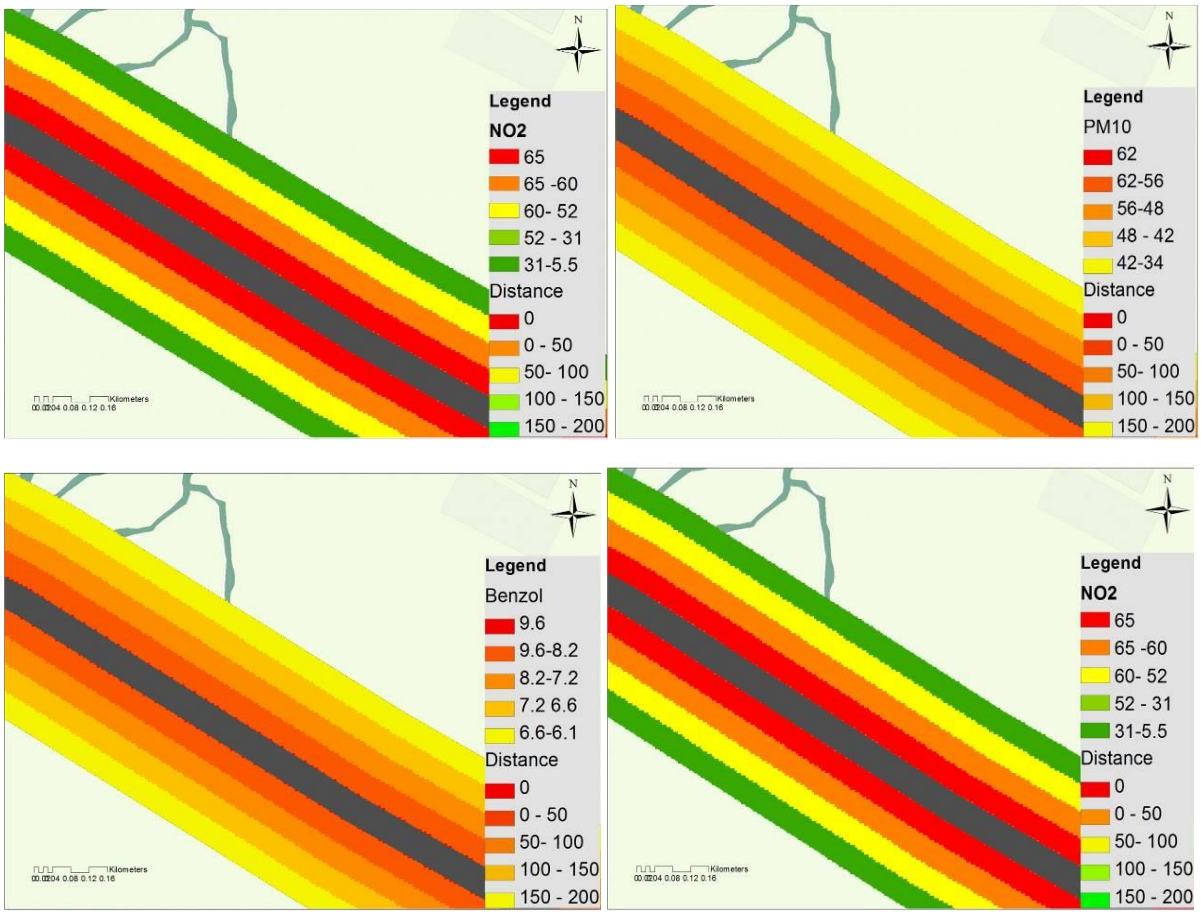


Figure 6.26: Car induced pollutants in major axis road in CSC

Source: Author, 2010.

Calculations have been carried out for all mentioned pollutant at 11 sections at certain major root like 60m ring road, the major road to the City, main commercial axis inside the city for different wind scenario. The most obvious finding was that the emission is more than threshold and the exceeding frequency is far beyond the allowable limit, particularly for the first two categories. For instance in the above presented section in Table 6.3 NO2: The 1 h mean values of 200 µg/ m³ is exceeded 85 times, (threshold is 18), While PM10: The 24-hour average of 50 µg/ m³ is exceeded 128 times, (threshold is 35). That is why regardless of traffic related mitigation measure, the pollutant cannot be eliminated totally that is why adaptation measure by introducing green buffer is necessary.

In order to show the direct relation of wind flow and amount of pollutant trapped, the minimum, average and maximum wind speed taken for the calculation process, see Table 6.4, shows different pollutant load for different wind scenario at the same section. That is why introducing wind corridor is one of the essential step in dealing with city's microclimate, due to the geomorphologic setting of CSC.

Table 6.4: Car induced pollutants in commercial axis in CSC for different wind scenarios.

Source: Author, 2010.

Component (µg/ m³)		**CO**	**NO**	**NO2**	**NOx**	**Pb**	**SO2**	**Benzene**	**PM10**
Total load	Appraisal values	-	-	40,0	-	0.5	20	5	40,00
	Min. wind (0.5m/s)	915	63.1	35.8	-	0.04	8.9	5.32	48.96
	Average wind (1.8 m/s)	471	14.6	26.4		0.04	8.3	2.92	28.04
	Max. wind (7.8 m/s)	339	3,0	19,4		0,04	8,1	2,21	21,86

6.5 Proposed Strategic Green Infrastructure Plan at a City level

6.5.1 Green Infrastructure Planning Concept

The developed plan helps to identify the CSC natural potential landscape resources and man-made urban green space, by creating a GI base map, then developing a concept for increasing, integrating and connecting this resource spatially, in a way to serve the selected ecosystem function, which is enhancing urban climate and adapting city to climate change and 'systemic' urban issues. For this purpose, after analyzing the GI typology at landscape and city urban scale map of basic protection area have been developed to act like a framework together with the above analysis for developing the GI concept, see Figure 6.27, illustrate protection area with natural potential areas.

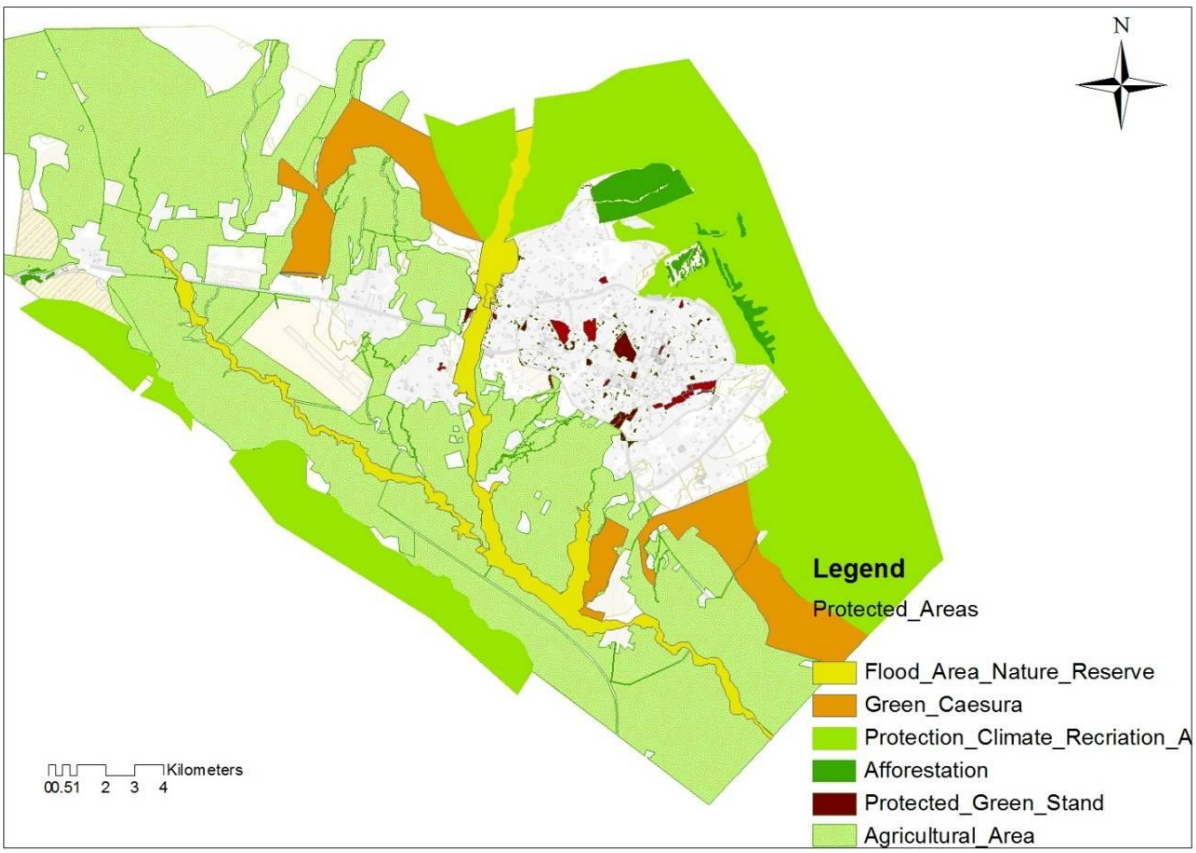


Figure 6.27: Basic GI typology with protection priority

Source: Author, 2010.

To accomplish the basic task of planning, "how to enhance quality of environment, quality of life and quality of place through a focus on green spaces, links and networks of green spaces". 234 Besides the site specific condition and analysis result, the author investigated the CSC as the built-up scale, and landscape scale correspondingly in developing the GI plan different strategy has been adopted with strong interlink in-between them.

Addressing the built-up area, under the light of the analytic part, it is obvious that according to all standards a considerable amount of green should be added. Moreover, as adaptation strategy to temperature increase due to climate change the percentage of green must be increased in the thermally polluted over massive built-up area. In the densely populated area that identified as area of priority some new parks with considerable size have been developed particularly at E, S and W part of the city, and nearby the highly deficiency area, see Figure 6.28.

[234] Davies, C., MacFarlane, R., McGloin, C. & Roe, M. (2008) *Green Infrastructure Planning Guide*, *Version 1.1*.

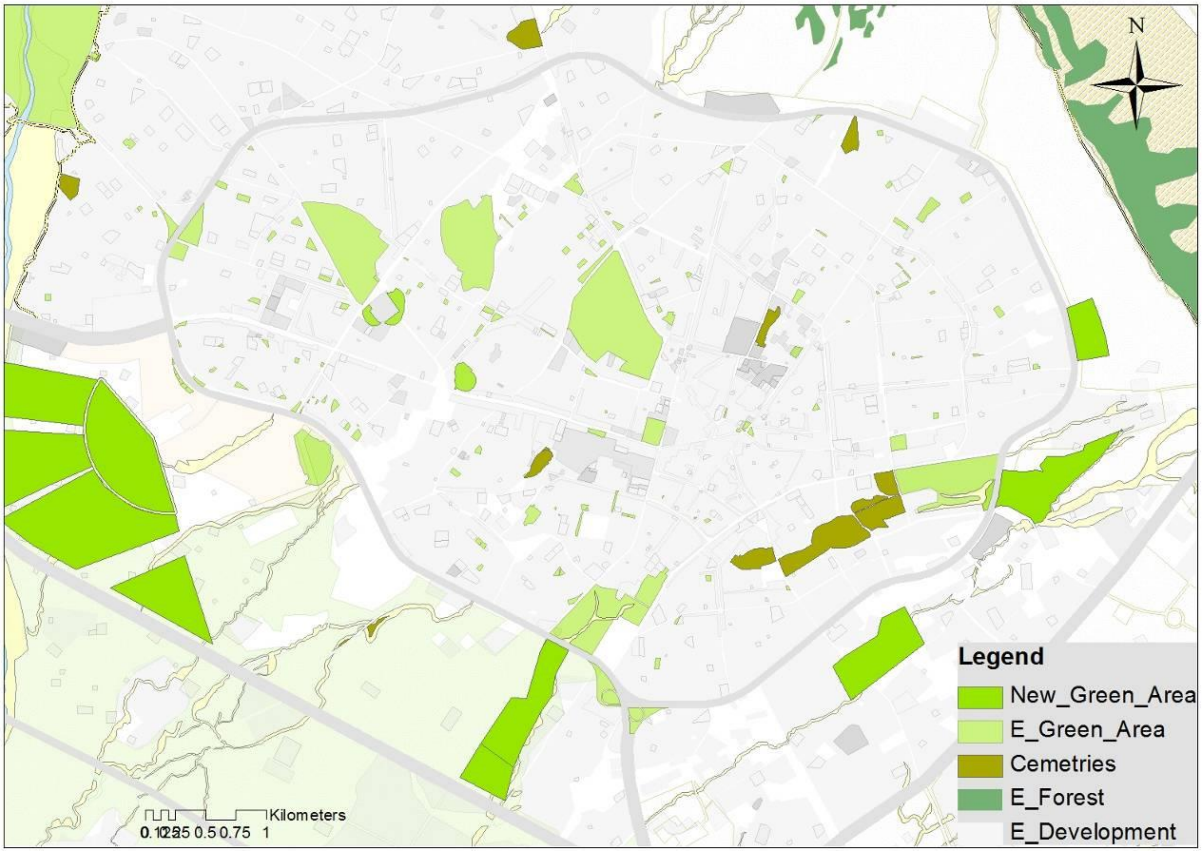


Figure 6.28: Proposed new city parks and green area in CSC

Source: Author, 2010.

It is logical that the increase of conventional urban green space in that large extent to address the need in built up areas especially in the City Center and inside 60m Ring road, is not feasible and coast effective. Therefore, other mitigation should be adopted in the built up areas. One of the appropriate measures is Living-roof or green-roof. Since the building typology and specifically physical characteristic (flat reinforced concrete roof) of the roof is quite suitable. Around 60% to 80% of the existing residential areas are roofs and the percentage of building at poor quality is high in the city center, that area under going restoration face. That is why it is feasible to mitigate the negative effect of dense built up area on the urban environment and urban ecology through vertical and horizontal surface of the building. Particularly adopting green roof concept is quite important for City Center considering the price of land and allowable Plot area ratio that is identified as 80% for residential and 85% for mixed use and commercial use. The former cannot be controlled while for the latter it is necessary that this percentage should be modified, by introducing lower percentage or identifying Green Space Ratio. Since the inbuilt area is totally covered by impervious surface. The green-roof mostly proposed as a radial system of rays connecting the focal point in City center (Sara Plaza) to the open landscape and existing GI typology, In order to reduce surface runoff and thermal pollution at the same time to act as a natural flow of air to the City center area. Moreover, green roof has been introduced in the main commercial axis in order to enhance the designated ecological function also airflow and air pollutant removal. See Figure 6.29, illustrating the proposed concept.

The vertical garden proposed to the main root in residential areas and main axis in the CSC that has heavy traffic volume and becoming main commercial axis in the CSC. See Figure 6.29. Many restoration processes are undergoing by converting large private owned home with large gardens to a mass of high-rise building without space. Therefore, it is most cost and time effective to introduce both vertical and roof garden along this axis, which reduce emission, save energy for heating and cooling and give vivid and unique scenic effect for this important axis.

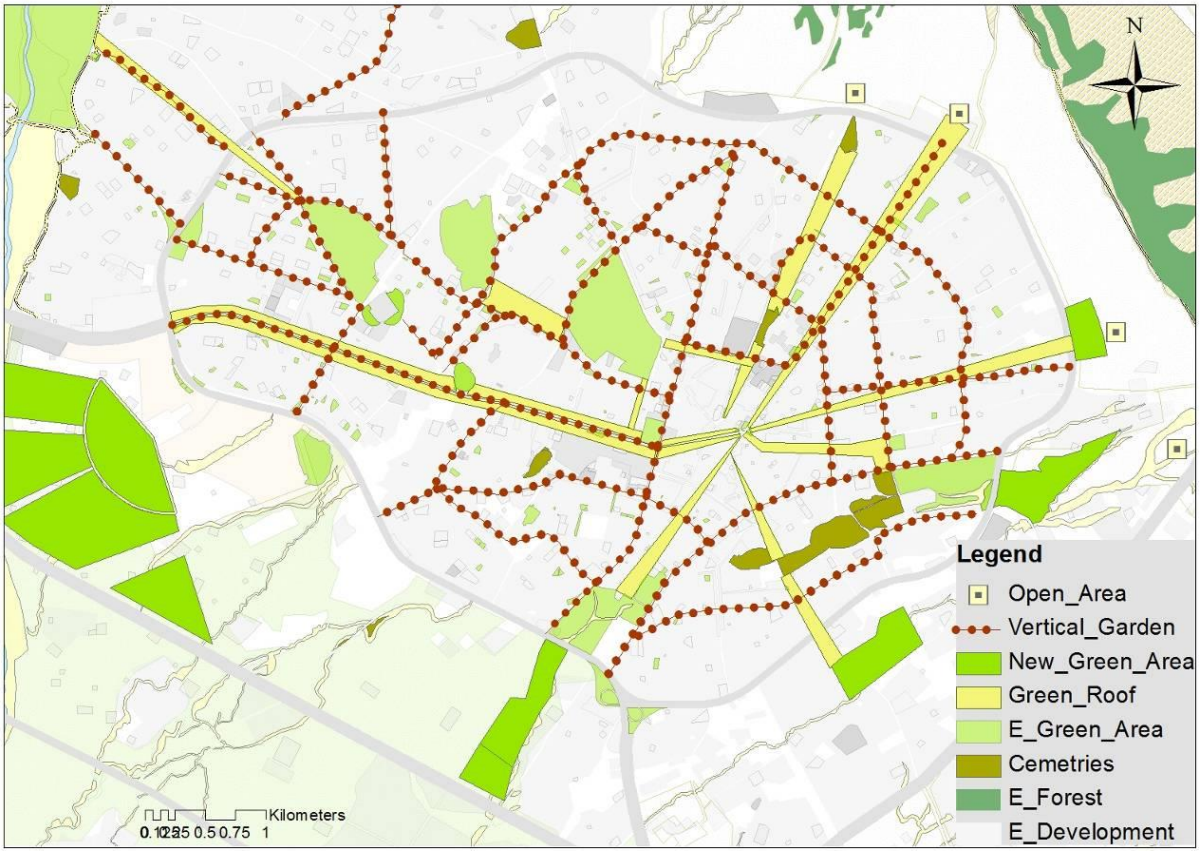


Figure 6.29: Proposed Green roof and Vertical garden in CSC

Source: Author, 2010.

Another strategy for the built-up area that has been adopted is enhancing the climatic related ecosystem services of the existing small-scattered isolated gardens, by connecting them to develop potential ventilation corridor. Since "a large number of smaller green spaces with their sum effect can contribute to a reduction in the thermal burden or the heat-island effect, as long as these green spaces are closely networked and exhibit a sensible arrangement from the perspective of the urban realm (e.g. corresponding with main ventilation corridors)". [235] To accomplish this a net is created through connecting the existing GI by introducing net of new street tree and limited green link or green way in the built-up are, see Figure 6.30, that illustrate net of existing and proposed street tree along main axis and important green links (green way).

[235] Whitfort, V., Ennos, A.R. & Handley, J.F. (2001) *Landscape and urban planning: "City from and natural process" – indicators for the ecological performance of urban areas and their application to Mersevside.*

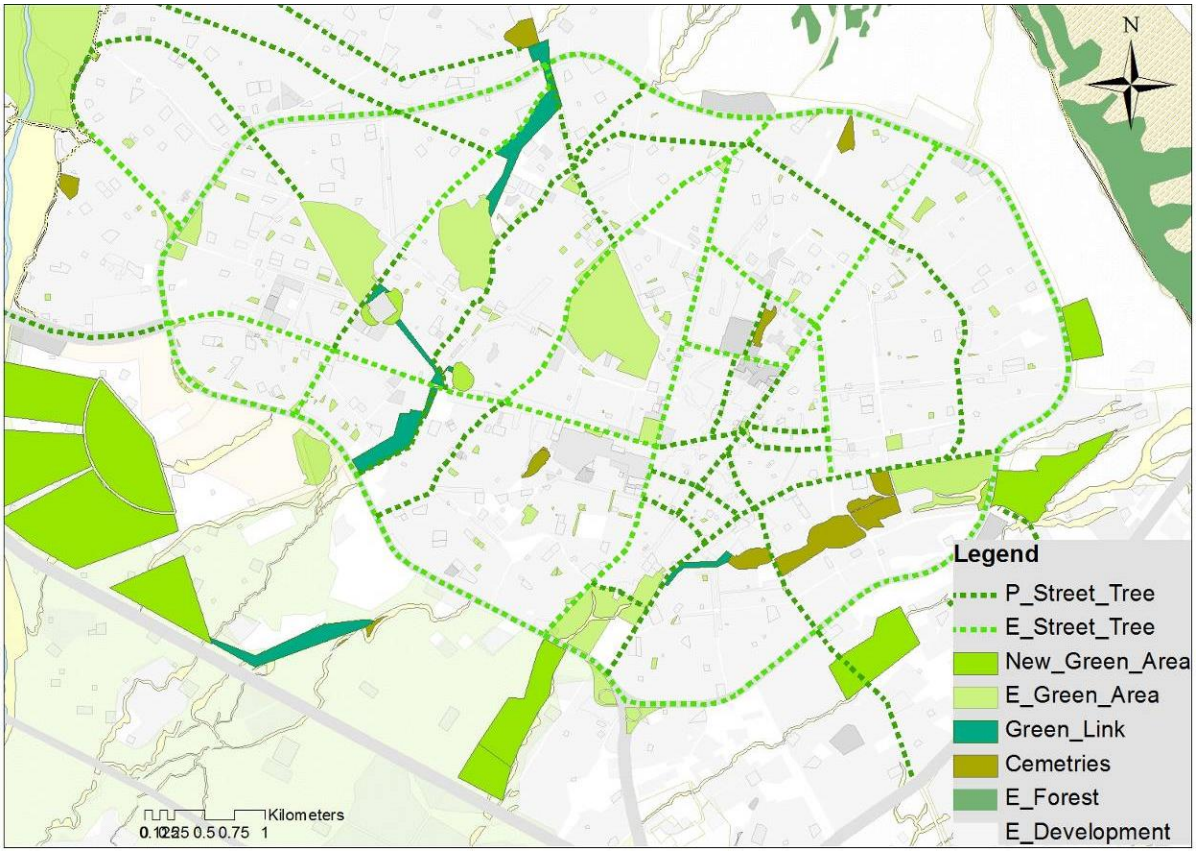


Figure 6.30: Proposed network connection through Green link and Street tree

Source: Author, 2010.

With the purpose of attaining equally beneficial effects on the emissions condition of particles and gases, a extensive planting larger than 10 m wide is necessary, in this sense the green buffer along the main root is designed, since the existing street tree is not having advantageous effects on emission reduction. The buffer of 50m width has been designed along the 60m and 100m width road. It is worth to highlight that for some part of 60m ring road this was not implantable because of existing development. See Figure 6.31 that shows the proposed buffer also areas of conflicts.

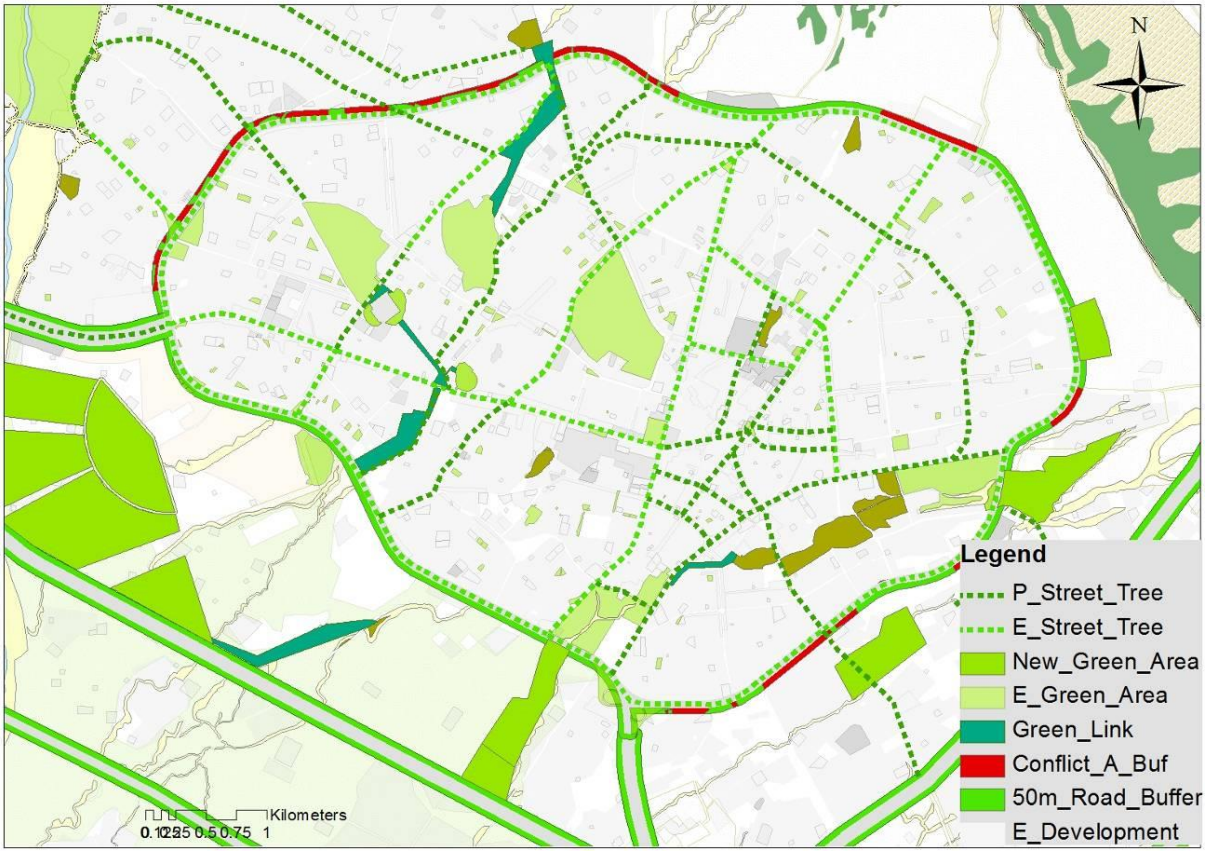


Figure 6.31: Proposed Green buffer around major axis

Source: Author, 2010.

For the urban fringe and landscape scale, the concept of proposed GIP focuses on the Main GI element (Chap-Chaq) valley connecting the existing city with the new development and the Green belt around the existing city with rays of green corridor penetrating the existing and new built-up area. It is important to shed light on the green concept of new Master plan based on the enlargement of the existing green area around the main valley and additional linear green line on the base of seasonal small wadi.

GI plans can produce a framework for future development while safeguarding that substantial natural resources will be preserved for upcoming generations. [236] The landform and geomorphologic setting of the CSC particularly the mountainous range in N and NW set a natural barrier for development at that direction, but this give a unique outstanding natural landscape composition. This supports the idea of creating green belt reserving open spaces around the city, and in between it and the mountains' ranges, regardless of the valuable scenic effect from the landscape's point of view. See Figure 6.32. Moreover introducing green belt is preserving the existing urban form by maintaining the shape and limiting the growth. Since urban from of historical city transformed from brain cell shape to inhomogeneous amebic shape limited by ring road. While the new form by the new master plan is irregular shape that cannot described with a specific description.

[236] Benedict, M.A. & McMahon, E.T. (2002) *Green Infrastructure: Smart Conservation for the 21st Century.*

The function of green belt is not only limited to scenic effect or urban form and controlling urban growth, but rather it has very important climatic related ecosystem services. Due to morphologic setting of the city, Introducing green belt at the N part of the city will service as a natural barrier for surface runoff flow from the mountain to the City, enhance infiltration capacity which has a positive effect on both surface and groundwater recharge in the area particularly the Karez system and reduce the erosion effect. It enhances urban microclimate recognizably through reduction of urban heat island impact and enhancing carbon storage capacity.

Integrating green gray infrastructure and getting benefit from natural topography based on the digital counter model, some areas had been allocated as natural water retention area. This area can be enhanced as reservoirs of rainwater as well. Regardless of surface runoff problem solution other specific function of introducing green belt to the CSC are, filtering the heavily polluted down flow air at the week end, through filtering effect of planting particularly leafy and coniferous tree species at and around the gateway of the main route to the mountain. Moreover reducing the severity and intensity of the local Black-wind at wintertime is site specific advantage.

The blue way project has already started along the main river in the CSC, but it is rather limited to the certain patch and not integrated or took the whole GI system as one integrated elements, that is why integration and continuity will be the base of this natural brake between existing and new city. In this regard, Chaq-chaq and Qlyasan valley are important not only from landscape's point of view, but they are also an important urban element. See Figure 6.32.

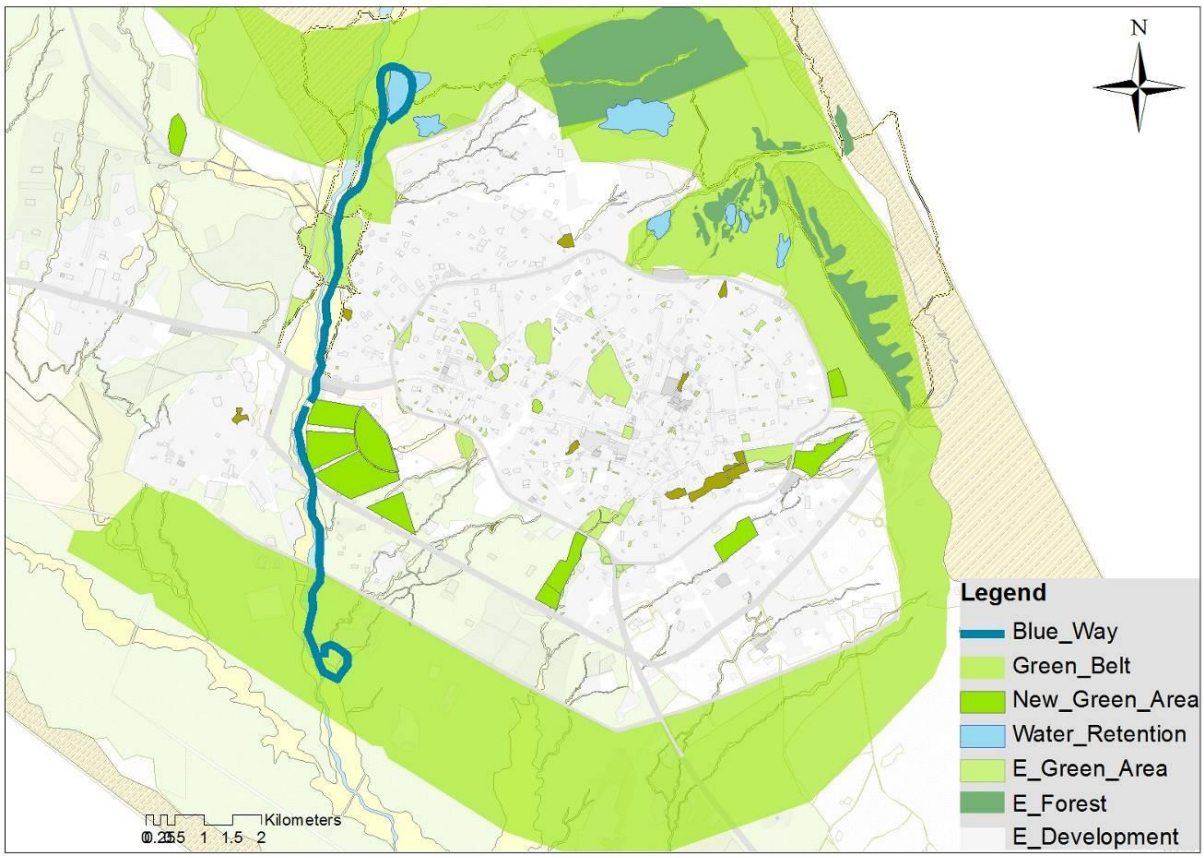


Figure 6.32: Proposed Green-blue concept at landscape scale

Source: Author, 2010.

The planed green belt is covering approximately 66.2 % of the existing GI in the urban fringe area of the CSC. The conflict of development at the most important climatic landscape element (hillside) should be prevented. For the undergoing projects, special measures like wind corridor free passage, should be implemented. The potential of feasibility for implementing measures is the large plot housing typology in which by setting restrict Green plot ratio and designed setback and side-back the integration of green and wind flow corridor can be garneted. In addition, other typology like orchard and agricultural farms can be allowed at certain part of the green belt, depending on the degree of soil fertility and availability of water.

Fundamental concepts from landscape ecology, which are applicable to urban GI for sustainable urban development and management embrace “a multi-scale approach with an explicit recognition of pattern: process relationships and an emphasis on physical and functional connectivity”. [237]

Developing green belt without connecting to the built-up area is serving neither the principal of GIP nor landscape ecology. That is why introducing rays of green acting like green corridors, reaching out to the surroundings open landscape and proposed Green Belt is one of essential concept of the proposed GI plan at the city level. It is designed to create a vivid network of green and enhance airflow. This will enhance all ecosystem services of the urban green and green belt itself as well. It enhance natural air flow if the corridor designed at a natural wind pass, in this regard summer is of major concern from city’s climatic point of view due to urban heat island and high sunshine rate that will enhance the trap of air pollutant in the city’s basin. Deriving from wind rose analysis, from May to September most prevailing wind direction is from SW and W direction except for July in which it is from NE and W direction. This gives a clear view for designing wind corridor. See Figure 6.33.

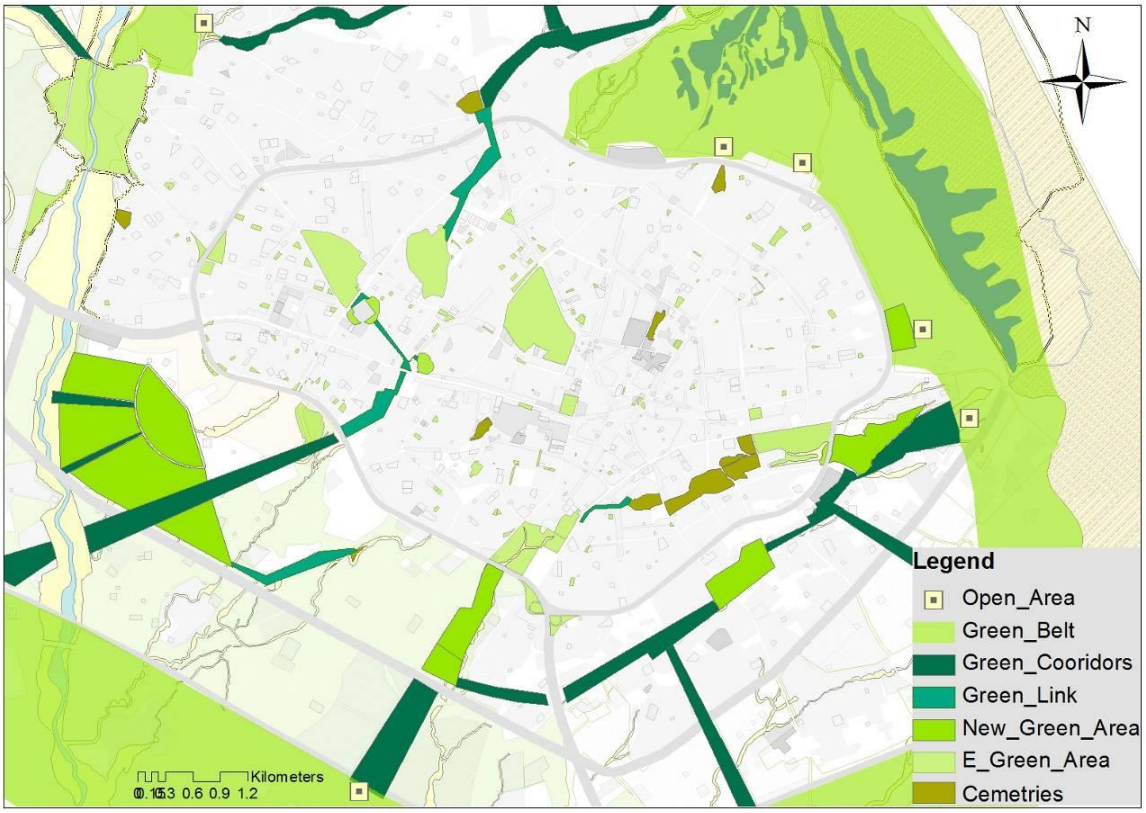


Figure 6.33: Proposed Green corridor between built-up and open landscape

Source: Author, 2010.

[237] Ahern, J. (2007) *Green infrastructure for cities: The spatial dimension.*

Moreover, to maximize other ecosystem services, like temperature reduction and decreasing surface runoff also most importantly providing biodiversity connection and integration, this corridor system has been designed in a way to act like a connected net work with the designed green link and green roof. See Figure 6.34 illustrating the connection between new and existing GI typology in and around the city.

Sustainable Movement Axis (Green Axis) has been proposed, it is working as a linear belt connecting the utmost NW part of the city to its NE part , within the new developed area passing through both new university campus (Sulaimani University and American University) and the new proposed city park at SW part. It is parallel to proposed blue way at the western part and it is an elongation to touristic part to new proposed city parks. It aims to enhance recreation as well as sustainable movement. It can be connected to the new area for development by rays of intensive street trees and vertical gardens. Moreover, other liner element is the Green over pass to enhance special continuity of all green elements at existing and proposed road cross sections.

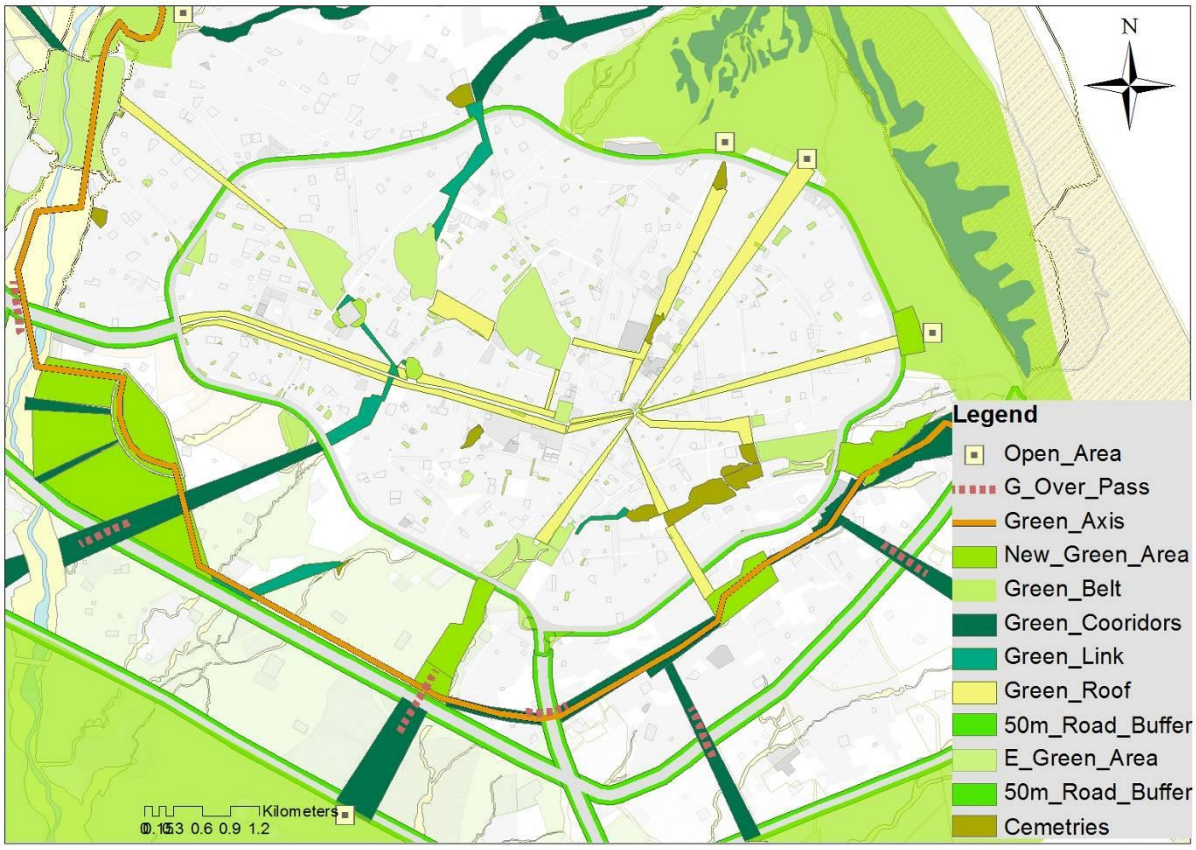


Figure 6.34: Proposed 2D and 3D Green network

Source: Author, 2010.

Another important landscape element is the city's gate way, historically the old city gate way was totally green with small urban forest at both side, but due to the city's expansion and change in municipality's border, naturally the City's gateway has been shifted in W direction. That is why due to GIP concept and degree of importance this element also has been considered in the plan, by introducing buffer along the major axis to the city.

6.5.2 Newly developed Area

6.5.2.1 Landscape scale

Since the area allocated by a new master plan for Cities growth has the same geomorphologic setting as the existing part, so the same climatic analysis in terms of thermal and air pollution, surface runoff and infiltration problem will be the same and repeat itself if measure have not been taken in this stage.

At a landscape scale, the extension of the proposed green belt is developed to act like a buffer in between the mountain range and new development to the west, second to reduce the impact of large sealing percentage in that particular important watershed area, and third to reduce the effect of flood risk due to morphologic setting. New development as a system of settlement areas is interrupted by linear park elements (oriented to the existing wadis) which connect the built up area to the surrounding nature, see

Figure 6.35.

In order to achieve a substantial and noticeable improvement of the city's microclimate at a neighborhood and quarter scale, a completely different planning concept should be adopted instead of the current one (small isolated scattered patches), but rather those open spaces are to be of considerable sizes and to provide a sound "people carrying capacity" depending on the quarters serving. Also thy have to be connected through green corridors to surrounding areas.

However, "The enhancement of qualities of life, place and environment at the local or neighborhood level is a partnership between private individuals and public authorities, to a large degree, although not exclusively, on privately held land" [238], but the new designated green area in new development area is based on the existing potential use of land. The existing greeneries are consisting of a complex of private owned gardens. This in terms of climatic and biodiversity point of view is accomplishing the functionality, but it is not achieving the main goal of providing "suitable and sufficient green spaces for recreation, amenity and conservation" for the community at this spatial level. The enhancement of the public right and social equity must be dealt with. This can be achieved by implementing 'public right of way' by introducing a "coherent infrastructure of green and green-grey links that provide routes and pathways for multiple purposes." [239], Secondly by implementing public-access policy at certain area by introducing recreational amenity that have public right, to ensure social equity.

Moreover, law does not fix the existing green plot ratio, which ranges from 80% to 90%. So, to ensure prevention of future potential change and keeping the climatic engineering and biodiversity function of this area, the existing green space ratio should be fixed by Municipal law. A new typology are in emerging called a farming plot, the same measure should be considered and adopted to this typology as well.

[238] Davies, C., MacFarlane, R., McGloin, C. & Roe, M. (2008) *Green Infrastructure Planning Guide*, *Version 1.1*.
[239] Davies, C., MacFarlane, R., McGloin, C. & Roe, M. (2008) *Green Infrastructure Planning Guide*, *Version 1.1*.

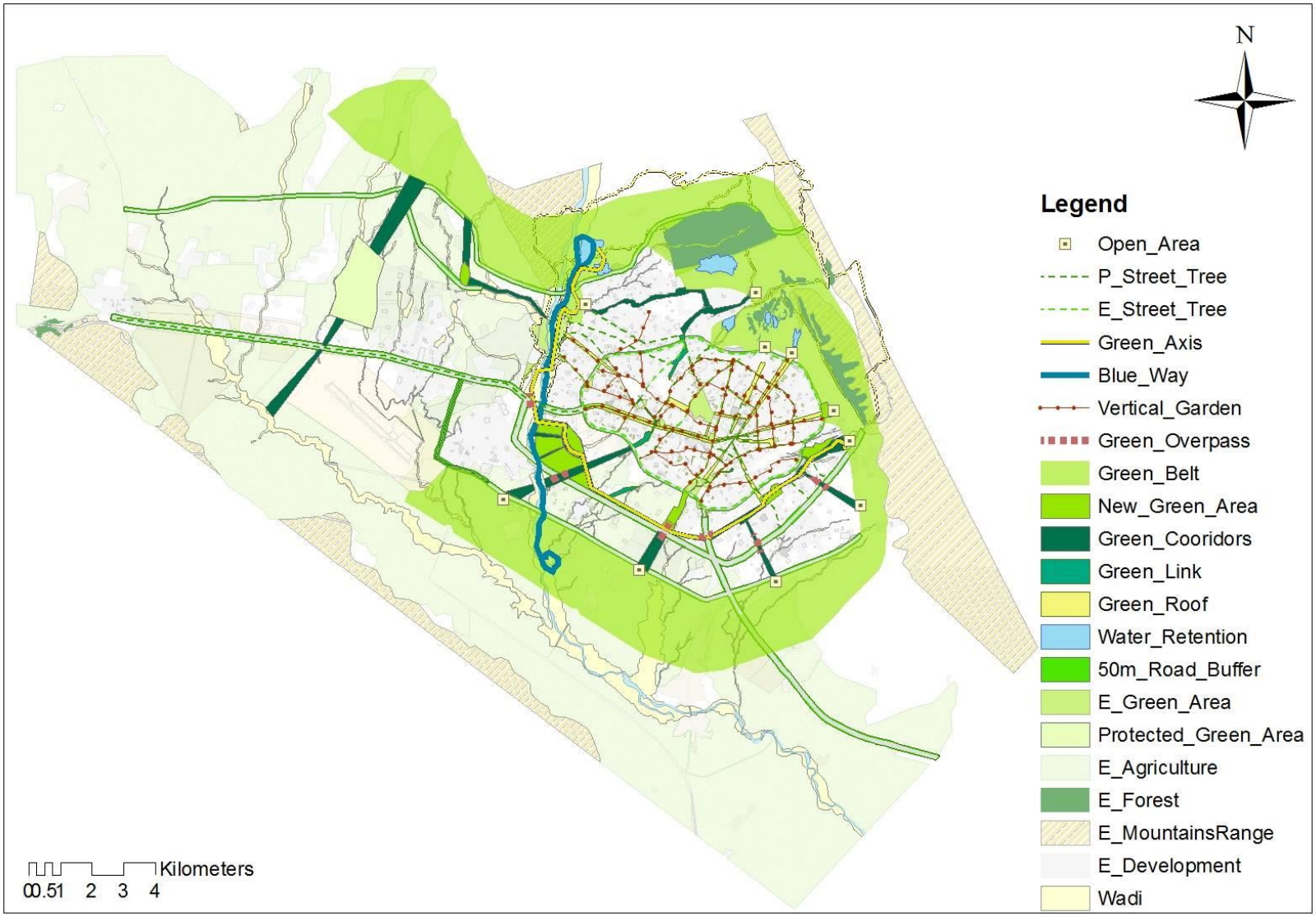


Figure 6.35: Proposed Green Infrastructure Plan at a metropolitan scale

Source: Author, 2010.

6.5.2.2 Plot level

Since residential area is composing more than 63% of the buildup area, so it is so important to enhance policies that increase previous surface at a lot level, by Introducing new plot area ration with green area ratio. The Biotope/Green Area Factor program of Berlin, Germany that implemented at the parcel or building scale can be taken as a model in this concern. Increasing previous surface will also grantee the environmentally sound management of ground water recharge in the area since the area that allocated to new urban development by new master plan have a very important footprint in this concern. Moreover, it reduces the amount of surface run off. In addition, standards for private infiltration caring capacity can be introduced especially in the 'Housing Complex Project' thus enhance the management of the surface runoff and reduce the flood risk.

To overcome the problem of special integrity that serves the principle of connectivity it is not only enough to introduce plot area ratio and green area ratio. However, Municipality should fix the setback line with strict identification of the use in building code. This measure is of up most important in the self-build house projects, since a lot of aspect of design at plot level is open to the owner.

To regulate and enhance the increase of green percent in newly developed area is achievable in the 'Housing Complex Project' typology; since by investment law they are legally bind to all standard that set by Investment Committee. While this typology of housing consisting low portion in a comparison of 'Self Produced Housing' typology. The challenge is to increase the green space ratio at each single plot and monitoring its implementation. In this typology, the whole plot can be regarded as a mass of impervious surface that affected the CSC climate dramatically. The municipality must guaranty that the same problem at the private scale does not occur again, by introducing the GPR.

6.6 Assessment of the Proposed Green Infrastructure Plan

In this section the quantity on the base of land use will be highlighted with the ecological performance after developing a green concept.

6.6.1 Proposed Green Infrastructure Plan and Land use share

The proposed GI plan (without existing urban green area) is estimated by 1100 ha. Different GI typologies have been used; green belt forms around 79% of total GI plan. See Figure 6.36. Existing agriculture, forest, Wadi and undergoing Tourism project are covering approximately 66.2% of 8736 ha green belt in the urban fringe area of the CSC. Regarding land use distribution of the rest part, variety of use can be integrated, but mostly the enhancement of urban forest with drought resistant vegetation typology, (indigenous tree species) is planned at N and E part of the CSC see Figure 6.36, shows existing and proposed share of green typology of green belt. Concerning proximity analyses the proposed green belt enclose around 23% of existing buildup area in NE, N and NW part, while it will enclose 90% of the existing and future expansion area. Moreover to evaluate green belt against natural vegetation cover of CSC, it covers 27%, 21% and 52% of forest range (B2), forest range, grazing, orchards (C2.1) and orchard (C3) correspondingly.

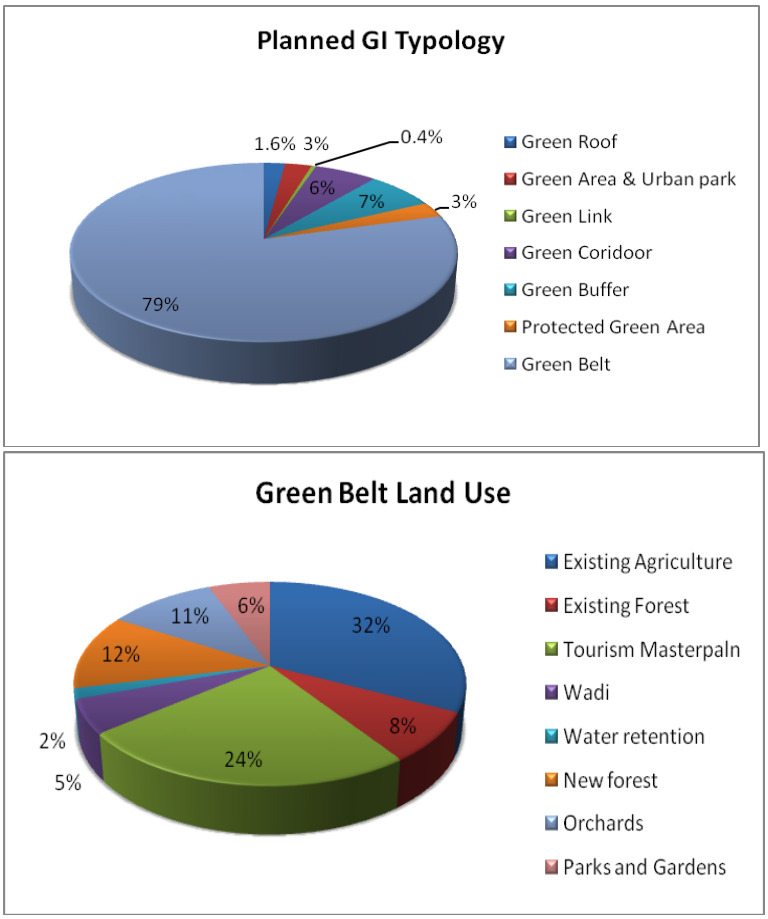
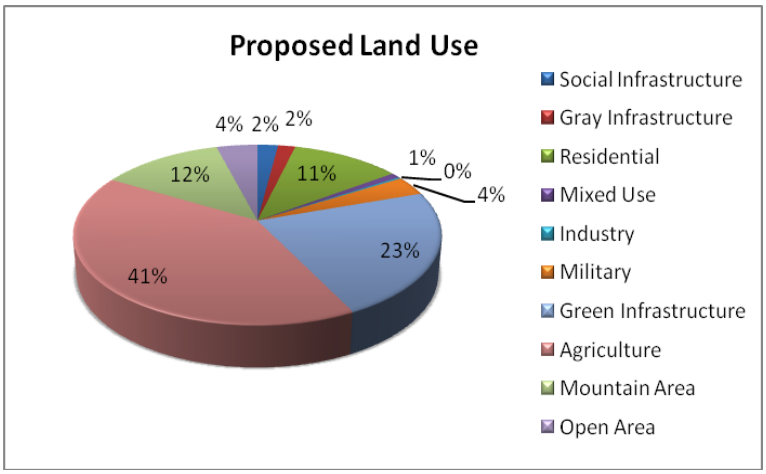


Figure 6.36: Distribution share of GI typology of proposed GI plan (T) and Green belt (B)

Source: Author, 2010.

To highlight the total sum of the proposed GI plan the distribution share of urban morphology categories in CSC have been analyzed for three different scenarios (Proposed GI plan, existing and expected (by Master Plan), see Figure 6.37.



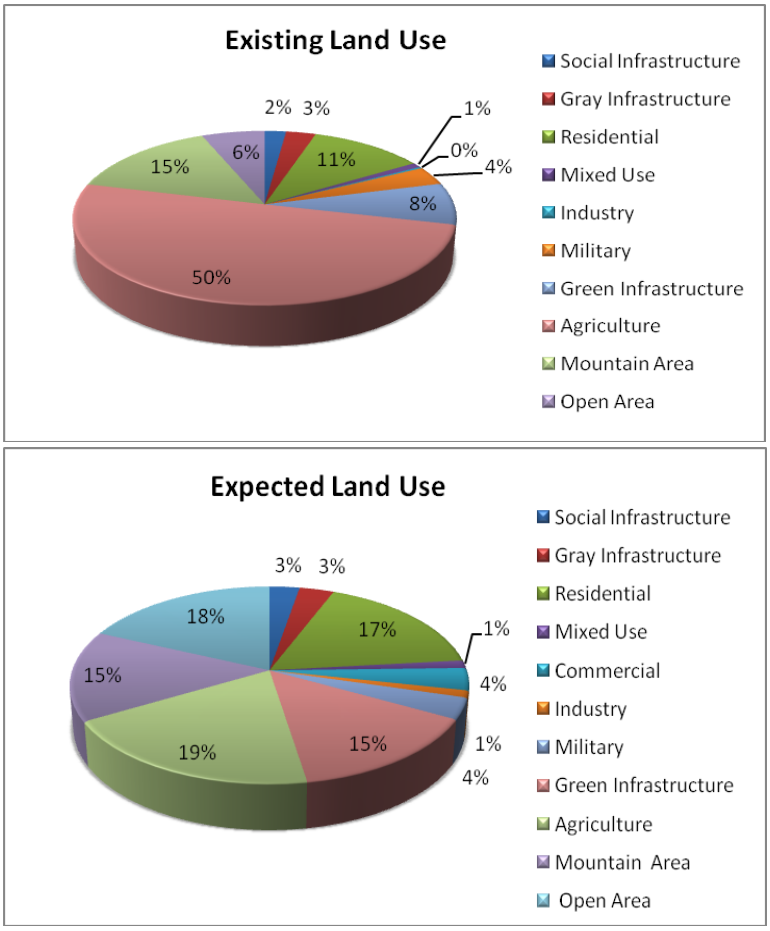


Figure 6.37: Distribution Share of proposed, existing and expected Land Use in the CSC (T, M, B)

Source: Author, 2010.

6.6.2 Ecological Performance

In order to illustrate the direct effect of percentage of green area or in other words 'Normalized Difference Vegetation Index (NDVI)'to climatic situation and ecological performance of the CSC under different scenarios, the author adopted similar concept to Whitford, V. et al, by using 'Urban Ecological Index Module'. In the course of this paper, one of the ecological indicators (biodiversity indicator) has been sorted out due to the lack of data. In this part the assessment for different scenarios: namely the existing situation, the planed situation according to proposed GI plan is carried out.

Due to CSCs specific characteristic, temperature management is of upmost priority. A considerable positive change can be recognized in city center and high density residential area, see Figure 6.38. Since the energy model have not been applied but with a Gaussian distribution function relating to classification of UMT density, decrease in temperature of 1-1.8 °C can be expected. While according to Gill, S.E. and al finding and basic parameter of 'Energy Exchange Model' with climatic situation, (since radiation flux to the earth surface and evapotranspiring capacity is more) decrease of more than that is expected. Also a recognizable different in the W, E and SE part of the city is observed.

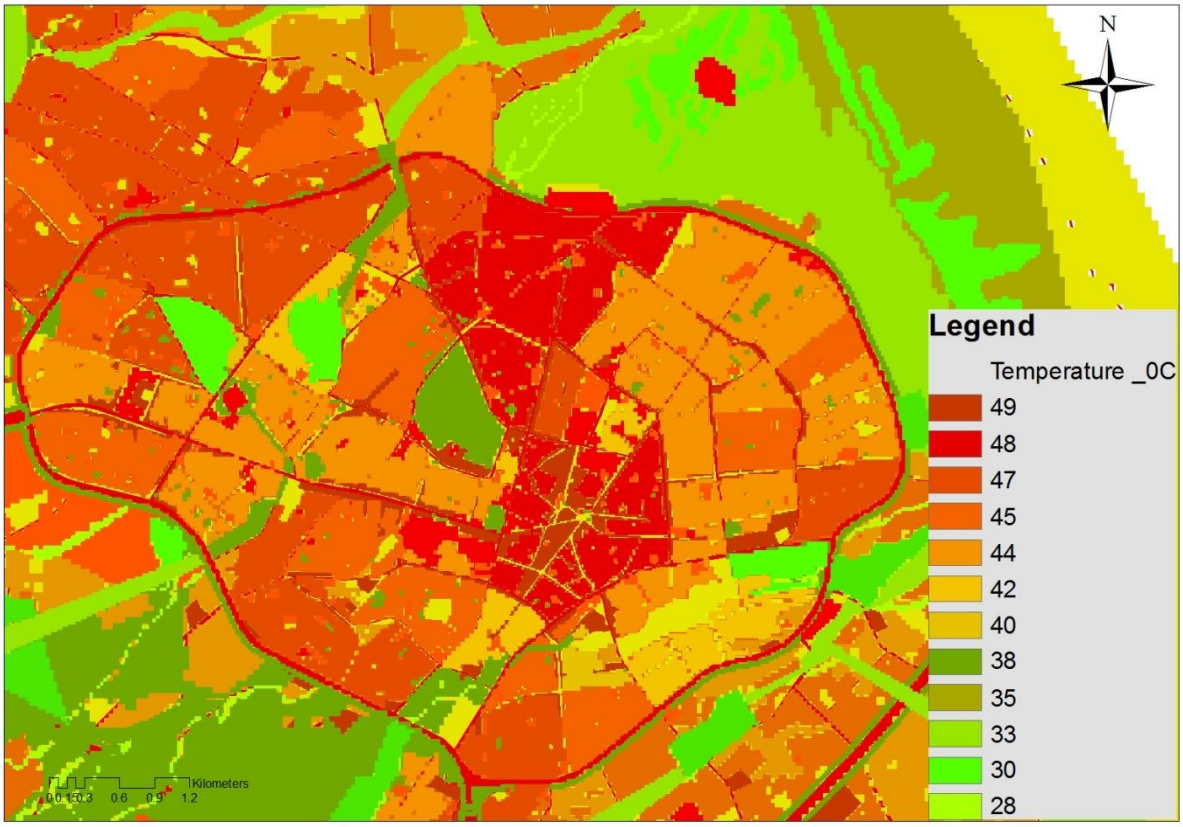


Figure 6.38: Surface Temperature map corresponding to vegetation cover ratio with GI plan in CSC

Source: Author, 2010.

The Berlin's Biotope/Green Area Factor program weighted green roof with intensive and extensive vegetation as 0.7 in a comparison to 1.0 to totally vegetated surface for urban ecological performance.[240] Accordingly, the ecological performance of green roof will be considered as 0.7. It is also worth to mention that the vertical wall and street tree ecological performance have not been taken into consideration. The analysis shows a positive effect of increasing 17.5% of green roof in the city center on the microclimate and surface runoff management (see Figure 6.39) increase of pervious area from 0.5-5% to 5-15%. Also a good coverage of E and S part of the city, While the N and NW the effect is not at the same level, which is directly proportional to percentage of green.

[240] Ahern, J. (2007) *Green infrastructure for cities: The spatial dimension.*

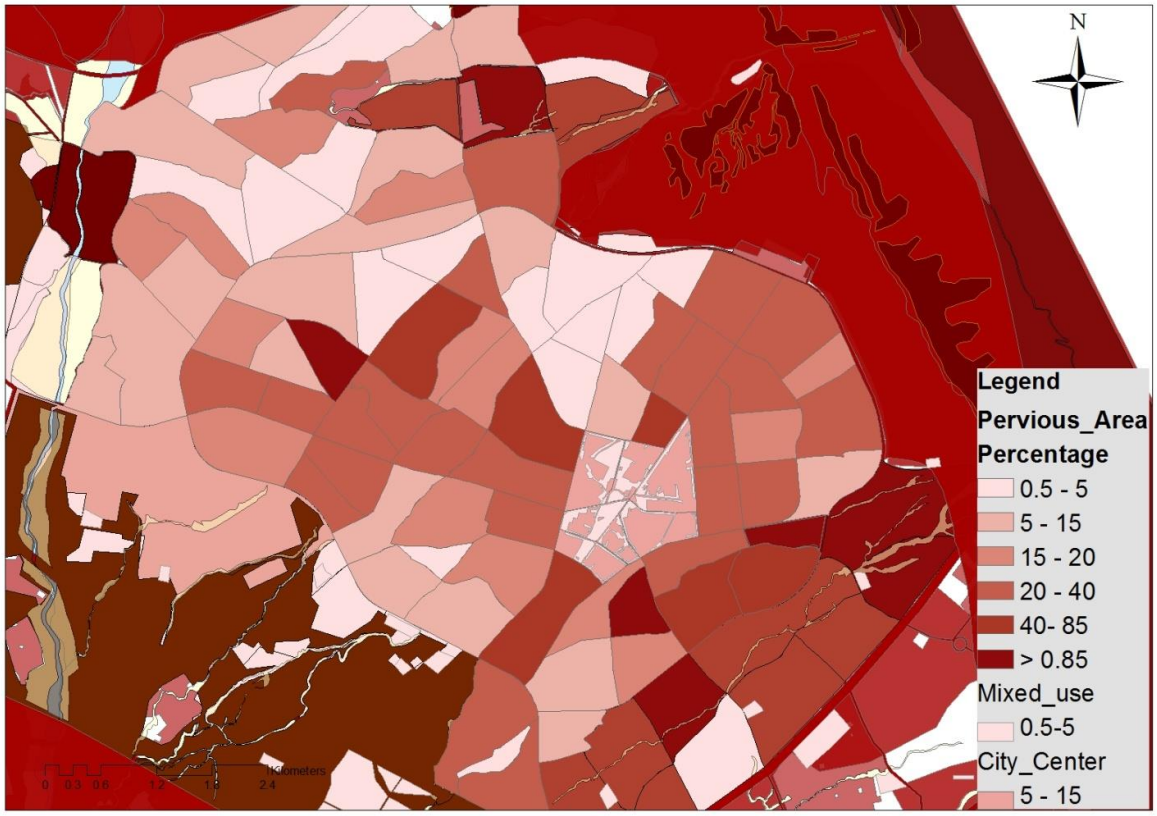


Figure 6.39: Planed proportion of evapotranspiring surfaces urban morphology sampling in CSC

Source: Author, 2010.

Never the less a number of neighborhoods at the upper part of section two still having surface runoff accumulation problem, that is why increasing green in one hand is not feasible to that limit in the other hand cannot mitigate the problem. That is why water retention area within green belt at the upper part of these areas has been introduced.

Regarding Carbon Sequestration capacity the total area covered by tree will be increased from 950 ha to 4600 ha, assuming the percentage of tree cover for forest and orchards, green link, green corridor, green buffer, urban park and tourism area 80%, 20%, 50%, 80%, 50% and 40% correspondingly. The effect is not with the same trend regarding buildup area inside 60m ring road; never the less considerable improvement can be recognized, see Figure 6.40. Moreover the green belt acts like a sink for the buildup area. For the city center around 20% of green roof accounted for this ecosystem services that is why to have better performance **Intensive roof-garden** type must be enhanced more.

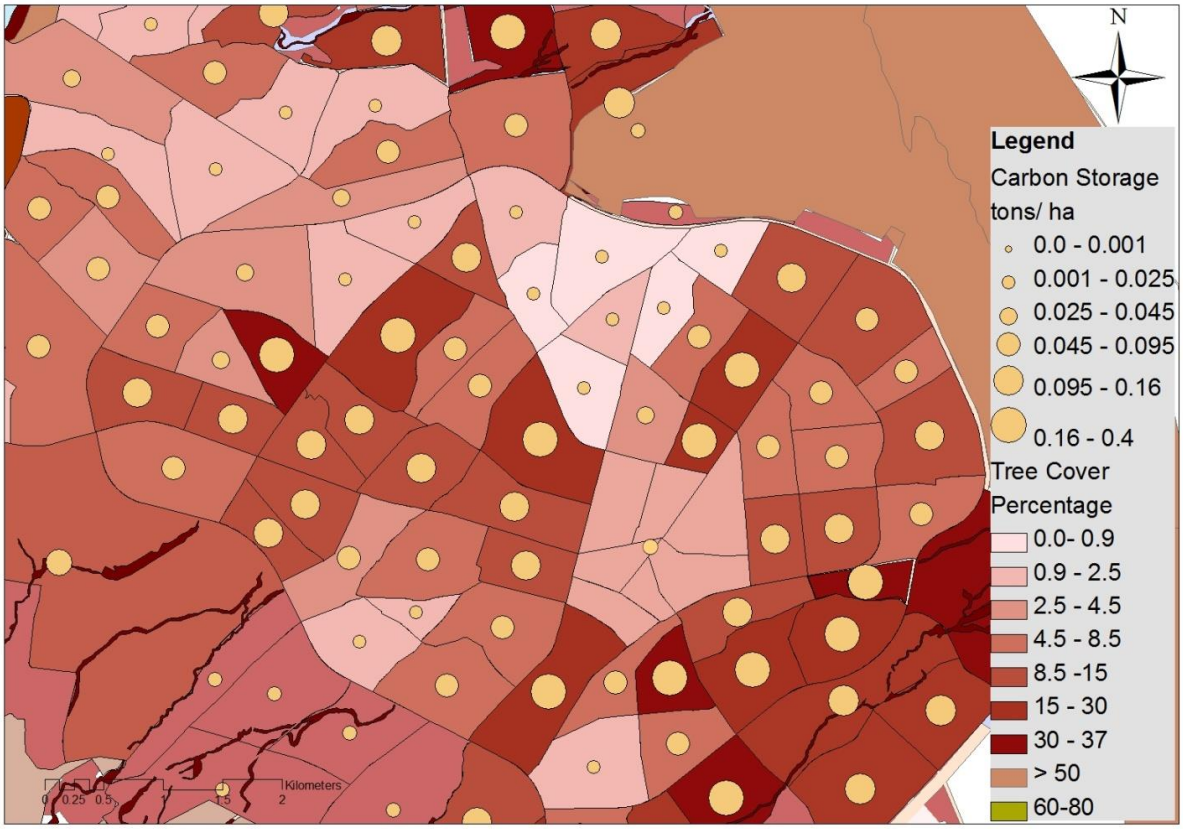


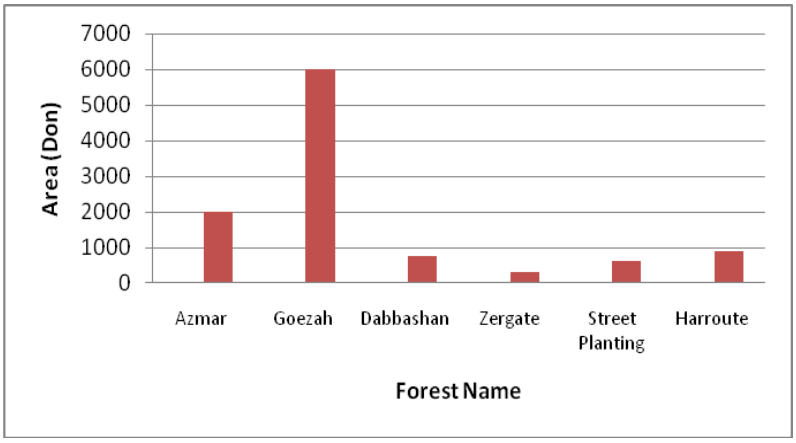
Figure 6.40: Planned proportion of tree cover percent and carbon storage capacity in CSC

Source: Author, 2010.

6.6.3 Feasibility discussion

A comprehensive study "Sulaimani Urban Forestry" (2005) was undertaken by BLUE FOX Geomatics Inc., which clearly states the importance of Urban Landscapes and Trees in the CSC, and the feasibility of enhancing the indigenous species and reforestation near the CSC.

While for the rest there are project undergoing on ground that can be integrated into this project, the reforestation process is continuous processes see Figure 6.41 that illustrate the reforestation of certain forest in CSC for the year 2005-2007.



*Ministry of Agriculture, General Directorate of agriculture Sulaimaniyah, Forest and orchards directorate, planning and implementation department, unpublished data.

Figure 6.41: Reforestation survey in CSC

Source: Author, 2010.

One of the natural barriers will be the basic fundamental element in greening process, which is water resource. Although the kind of green and tree species are recommended to be indigenous to the region and totally dependence on renewable water resource (rainfall), but in the hot dry summer the water will be a limiting factor for implementing the GI plan particularly at developing stage. The alternative solution has been considered like rainwater harvesting, the re-use of grey water. The city together with Coalition Provisional Authority (CPA), have worked on a new project of waste water treatment plant at the southern part of the city for treating swear and reuse it for irrigation purpose. In order to highlight the potential amount of water that will be available and can be used for greening and irrigation, see Table 6.5.

Table 6.5: Projected amount of treated Grey Water.

Source: Author 2010.

	Growth rate	Population	Total Consumption [m³/d]	Total Demand [m³/d]	Average Daily Sewage Flows [m³/d]	Storm Water Flow [m³/y]	Forecasted Treated Water [m³/d]
2009	-	831,495	212,453	229,243	141160	4578 766	127,045
2018 *	3.0 %	963,243	212,453	265,566	163,527	6,808 054	147,175
2033 *	2.5 %	1,429,423	302,296	365,619	194 516	6 808 054	175,065

*forecasted by CPA, (2004). Master Plan and Design of Sewage Network and Treatment Plants for the Cities of Dohuk, Erbil and Sulaymaniyah: Sulaimani Final Master Plan – Volume I of III Main Report.

For the N part of the city it won't be economically feasible to pump treated water from the waste water treatment plan in the S of the city in dry season. Moreover, to manage the cities climate in term of flood reduction and reducing erosion problem, Introducing clever water management e.g. storing of winter precipitation in underground, swales and artificial pounds would be recommended. For instance, the topographical situation in the north part of the city is quite suitable for introducing artificial ponds or lake. Since only by increasing green area inside the buildup area flood problem will not be solved.

So the integration of green gray infrastructure and managing the basic concept of GIP must be implemented. This will increase the feasibility of implementing the GI plan at the city level in general and particularly at the N and E part of the CSC. Moreover, it will be helpful to enlarge and introduce new "natural green areas" within the most dominant wadis consequently.

Another constrain is the soil formation (Limestone rocks laminated with heavy textured soils (salty clay soil)) at the up part of mountains in Goizha area, this area is already under covered by Tourism Master Plan and will not be dealt in terms of natural resource and will not cover the proposal GI plan. It is worth to mention that Karim, T.H. et al characterized this harsh ecosystem as a suitable biotope for wild Almond. According to the researchers the benefits is not limited to greening only but also retarding surface flow by making the soil and rocks more pervious to water, improves climatic condition, source of protein and drugs and most importantly it convert shallow soil and rocky lands to orchards of stone fruit in a short time span.[241] Therefore, for the mountainous range, this will be a unique solution that serves both purposes of greening and converting rocky or shallow land to productive orchards.

[241] Karim, T.H., Khoshnaw, K.H.B. & Ali, J.J.M. (2000) *Exploitattion of Shallow Soils and Rocky Lands in the Mountain Region of Iraqi Kurdistan.* Zanco Journal, Vol.12, No.2. pp 13-27.

7 Strategies for Implementation and Conclusion

7.1 Institutional and Regulatory Framework

7.1.1 Institutional Framework

At the national level, the Iraq Government still lacks clear planning structure hence no clear description of roles for the various institutions. The same applies for the Kurdistan region, which is a newly formed government.

There are various ministries with corresponding departments at the national level herein discussed are the key stakeholders in planning generally and specifically GIP.

The **Iraqi Ministry of Agriculture** responsibilities are “planning, implementation, and oversight in the areas of agricultural extension, veterinary services, agricultural economics/statistics, as well as quarantine policy development”. Agriculture in general contributes to the effect of green spaces in the country though on the other hand. See the clearing of indigenous plants.

The **Iraqi Ministry of Environment (MoEN**) is in authority for the failure of policy, planning, regulation and implementation of panels on topics that affect the environment. Also, the MoEN is responsible with observing and determining environmental misuses, and providing the awareness via education means about the importance of natural resources protection. This ministry is newly formed and at the time of compiling this thesis, no clear regulations exist as to how it carries out its mandate. There are various departments set under this ministry, including: the Air Quality, Water Quality, Environmental Impact Assessment/Audit (Report), Monitoring and Evaluation of Soil, Assessment of Contaminated sites and Management of Chemicals Departments.

The **Iraqi Ministry of Construction and Housing (MoCH**) is in charge of the oversight of policy and planning for significant facets of the ‘construction and housing system, including roads and bridges outside the municipality’s physical boundaries, housing and public buildings’.

The **Iraq Ministry of Municipalities and Public Works** responsibilities refurbishing and refining vital service facilities (water, sewage, trash collection). The Ministry plans to “improve and extend upon Iraq's conservation efforts and capacity”.

The **Ministry of Planning and Development Cooperation** is responsible for planning and ranking growth and rebuilding projects, mainly through its role in donor coordination and in the preparation of the capital budget. The Ministry have a different specialized organizations: “the Central Statistic Organization, the Central Organization for Standardization and Quality Control, the De-Mining Commission, the NGO registration office and the National Center for Administrative and Technological Development”. The Foreign Investment Promotion and the Economic and Social Fund are units that grants loans are also managed by the Ministry.

The **Iraqi Ministry of Water Resources (MoWR**) is responsible for water management of surface and groundwater supplies. The MoWR attempts to balance the challenging demands of “irrigation,

municipal and industrial water supply, hydropower, flood control, and environmental needs including marsh restoration". [242]

At the Kurdistan Region, there are also ministries, which have being set up herein discussed are the key stakeholders. There are equally the Ministries of Agriculture and Water Resources which carries out the duties equivalent to MoWR and Ministry of Agriculture at the Iraqi national level, Housing and Reconstruction, Natural Resources which carries out duties similar to the ministry of Environment at the Iraqi national level as well as the Ministry of Municipalities and Tourism and Ministry of planning.

There is a recently completed project named 'Green Belt of Erbil City' at the CSR. This is a step closer towards realizing a green/landscape plan for the whole region as well as the city of Sulaimaniyah yah. However, this project has not been approved yet, and the implementation agency has not set up yet.

The Ministry of Municipalities and Tourism is the main body in charge of planning at the city level. The Department of Tourism is under this ministry and is responsible for the Tourism Master Plan of the city. They are responsible on areas of so-called touristic place, which mostly are green areas. There is equally the planning department under this ministry. It is equally involved in planning the green areas including neighborhood gardens and city parks. The department of Gardens that belong to the Municipality of each city is responsible for detailed design and implementation of the urban green and street landscaping (tree planting). While the department of Forestry belongs to Ministry of agriculture is responsible on planning and implementing urban forestry.

7.1.2 Legislative and Regulatory Framework

It is a fact that in Iraq after the dramatic political and institutional change, the legislative and regulatory framework of Iraq remains in a state of flux. The first priority is the rebuilding of Iraq's infrastructure and services. Most of the rules and regulation are going under the process of regeneration or revisions. Both related ministry of Environment and Planning are established after first governmental Cabinet has been announced in 2004. The author does not have any access to any official document about Nature conservation in general, Landscape, and green protection in particular. The case is more or less the same in the Kurdistan Regional Government (KRG), which looks like a new country since 1991 with new laws meant to steer the region to economic and social development. Consequently, planning laws and regulations, and planning practice are in the early stages of development within the region. There exists a quasi-separate legislative and regulatory framework based on laws and regulations of Iraq, but often updated independently of the rest of the country. It is worth to mention that certain laws that have been issued since 1950s have not been updated at a national level.

7.2 Barriers against Successful Implementation

There exists several barriers for the successful implementation of GI at the national (Iraq), and regional (Kurdistan Region) Level as well as at the city level. Most of these barriers are more or less the same for many other developing countries, but in the case of Iraq and particularly KRG due to the three preceding wars that the country passed through and internal conflict some other specific barriers can be pointed out. So two main groups can be highlighted as follows:

[242] U.S. Department of State, *Iraqi Government*, http://www.careers.state.gov/iraq-jobs/ministries.html#COM,

7.2.1 Barriers at a National Level

This includes constrains at the Iraqi national level which are common to developing countries for planning process in general.

- **Legislation issue:**

There is a general lack and/or inadequacies in the existing legislation. Planning and environmental laws are not detailed and equally not well coordinated. The country has for a long time not participated in international and regional environmental agreements, which is one of the serious barriers. There is urgent need of updating the issued laws and under the current administrative, climatic and environmental circumstances.

- **Public participation:**

There is lack of public participation in planning process in general. It should be legislated by law and activated by public education and awareness of environment protection at regional, provincial municipal and community level.

- **Public education and awareness:**

There is lack of public awareness of the importance of the natural resource and environment protection at the macro level. In addition, there is lack of the degree of importance of GI network in and around the city.

- **Organizational and administrative issue:**

There is no effective institutional or administrative body for environmentally sound management and/or sustainable development and planning. Because there are different governmental organizations dealing with planning and particularly GIP process, this had the duality effect on planning process.

- **Organizational and administrative Gap:**

There is no integration strategy between different key Sector Stakeholders and planning body, this lead to spreading the efforts and most of the time contrasting interests.

- **Technical and Man skills:**

Whilst awareness of GI is growing and emerging in developing countries particularly in Britain, this integrated comprehensive approach in planning can be adopted by developing countries. However, insufficient knowledge and experience essential to emerge and drive the GI program advancing from strategy to implementation is a serious constrain. Moreover, lack of necessary technical instrument for climatic and environmental monitoring and data processing; as it has been illustrated the author depended on several source and assumption mechanism for forecasting effect of climate change and illustrating CSC climate situation.

- **Post War Planning Process:**

Immediate focus is on the rebuilding of the country. There is general lack and/or weak monitoring and implementation strategy and policy at all levels. Since in most cases there is a large gap in legislative levels for instance national and Kurdistan Government Level.

7.2.2 Barriers at the Regional and City Level

These are barriers specific to the case study region area as well as the case study city.

- **Legislation issue:**

As mentioned earlier in Section 6.1.2 there lacks comprehensive up to date legislation and regulations related to planning and particularly GI. Beside law legislation and law update issue.

Another important point to be highlighted is the conflicting law and regulation by different parties due to the lack of integration. This leads to the clash of interest and because of the political state of the country through history and current economical dominated view of key stakeholder always environmental issue was the missing and neglected side of this conflicts. This can be solved by a comprehensive review of all regulation at each domain at both national and regional level.

- **Political and Administrative**

Throughout the history of the planning at national level, it has been connected to politics in the sense that some time the planning policy losses technical sense. Meanwhile the planning policy should be based on environmental, social and economical means. While in Iraq and Kurdistan Region there is no effective institutional or administrative infrastructure for planning and implementation process because there is different governmental organizations dealing with planning, this had the duality effect on planning process because of lack of effective integration, at all level.

Political wars and internal conflicts have led to general lack of interest in the GI. In addition, the Economical dominated view of the government and key stakeholder. Another serious problem is the Landmines problem. Around 20 million landmines, mostly spread along the Iran border line – during Iran-Iraq War from 1980 to1988–, contaminate Iraq. Moreover, there are millions of unexploded cluster munitions from both Gulf Wars through the country. In Iraqi KR only, 3,512 minefields have been listed, covering an area of 788 Km^2. [243] Also, unlisted new laying mines by Turkey since 2008 across the north border area, have caused further contamination. Tackling the threats and the demand for discovering and implementing useful solutions, will need durable and longstanding planning, funding and a new political agreements with the surrounding neighbors.

- **Natural barriers**

As it has been emphasized before the for implementing the GI plan the renewable water resource is the only source particularly at a regional scale, but it is a fact concerning the typology of different plant species that is commonly in use in the CSC the drought and water will be a limiting factor. (This has been covered in chapter five in detail.

Another natural barrier is Climatic barrier temperature increase due to climate change and urbanization effects. “One caveat to the potential of green cover in moderating surface temperatures is the case of a drought, when grass dries out and loses its evaporative cooling function.” [244] The urban green space in CSC consist mainly of high percentage of irrigated lawn that may loss its cooling function within climate change effect, unless counter measures are taken. The soil erosion problem due to over grazing and human misuse of natural forest in the mountains area, this may cause constrain as well.

- **Funding**

Funding is the fundamental issue in putting any plan or project in to action correspondingly If GI is to be taken forward as a serious contributor to the economic offer of the City Regions then the funding question needs to at least be approached at an early stage. This need political and leadership support, which can only be granite by a common understanding of sustainable principle and environmental integrity.

It is a fact that the preceding wars have a major influence, but nevertheless the sense of responsibility towards environment and sustainable use is lacking as well there is a general lack of political support to projects related to environment in general and in particular GI. This is due to general understanding to Green concept and environmental considerations. The stakeholder and

[243] United Nations Development Programme (UNDP), The Republic of Iraq, *UNICEF and UNDP concerned Iraq unable to meet its Ottawa Mine Ban Treaty obligations*, http://www.iq.undp.org/UploadedFiles/Sections/3bd76bbb-48ae-4f63-aa14-da69e3dab6d9.pdf

[244] Gill, S.E.; Handley, J.F.; Ennos, A.R. & Pauleit, S. (2007) *Climate change and cities Adapting Cities for Climate Change: The Role of the Green Infrastructure*. pp(115-133).

decision maker are mostly having short-term economical dominated viewpoint, the environmental dimension is missing or have less priority in this stage.

7.3 Strategies for Implementation

7.3.1 Proposing Legislation

The author does not have any access to any official documents about Nature conservation in general and Landscape and green protection in particular since both related ministry of Environment and Planning are established after first governmental Cabinet has been announced in 2004. That is why the German model will be highlighted to propose likewise regulation, or is used as a base model to develop and update the existing regulation. The author's aim is presenting related regulation to stress the degree of comprehensiveness and integration in all related regulatory law in German model.

In this concern, the author focuses on the German Regulatory structure, and some related regulation to nature conservation will be highlighted. As stated in Federal Building Law "the aims of nature and landscape protection are to make sure that our natural assets (soil, water, climate, fauna and flora) can regenerate and can be used sustainably in future" [245]**.** The aim should be common for developed and developing countries in this concern. That is why the author will mention the most related section that can be adopted, or used as a base for passing regulation and law.

In Germany, "Landscape plans and open-space control plans serve to realize the goals of nature protection and landscape preservation. They comprise an assessment of the natural conditions as well as the land use requirements of the area in concern. The natural potentials to be studied include climate and air hygiene along with an ecological evaluation of the established conditions and conflicts of land use." [244] In addition to Federal Building Law there are "Federal Nature Conservation Act (Naturschutzgesetz, NatSchG) and Federal Emission Control Act".

Specific section in Federal Building Law that set to serve the regulatory options that related to the papers investigation topic (as cited in [244]):

§ 1a (2). Sealing of soil surface has to be restricted as much as possible.
§ 1a (3) Compensation of intrusions upon the natural environment
§ 1 (5) Urban development planning has to be sustainable, integrate social, economic and ecologic demands and assume the responsibility for future generations.
§ 1 (6) Aspects have to be taken into account when establishing urban development plans:
No. 7 Environment protection aspects, including the conservation of nature and landscape management,
A) The consequences on animals, plants, soil, air, climate and the interactions between them, as well as the landscape and biological diversity,
D) Environmental effects on human beings and their health as well as on the population as a whole,
E) The avoidance of emissions...,
F) The use of renewable energies as well as the economical and efficient use of energy,
G) The presentation of landscape plans and green open space structure plans as well as of other plans, especially concerning water rights, waste rights and pollution control rights,

[245] Ministry of Economy Baden-Württemberg in cooperation with Environmental Protection Department of Stuttgart. (2008). Climate Booklet for Urban Development Online.

H) The conservation of the best possible air quality in areas where the fixed emission protection limit values are not exceeded

I) the interactions between the different aspects of environmental protection.

§ 2 (4) an environmental impact assessment is required for any kind of development.

§ 5 (2 a) Allows equalization where interference in nature or landscape is expected.

§ 9 (1) Of the Federal Building Law which include the following subsections

No.1 a Balancing regulations for nature protection.

No. 10 Properties (and their uses) to be kept free of development,

No. 15 Public and private green spaces such as parks, continuous, allotments, sport and recreation facilities, tents, pools, cemeteries,

No. 18 (a) Agricultural property and

(b) Forests,

No. 20 Property or measures for the protection, care, and development of earth, nature, and landscape

No. 25 (a) Planting of trees, bushes, and other plants,

(b) Preservation of plants, trees, bushes, and water

7.3.2 Developing a Planning Hierarchy

This section covers the general overview of German Spatial Planning System, with going in to detail to the landscape planning part, highlighting Stuttgart City as an example. It also covers introducing the planning bodies in Iraq by adopting descriptive approach and highlighting the administrative and political hierarchy. Then proposing the hierarchical planning structure to Iraq using the German model as a base is included.

7.3.2.1 Spatial Planning in Germany

The German Spatial Planning System is a well-structured system that starts with national scale up to project scale. Spatial planning covers comprehensive and/or sectoral planning. While Comprehensive planning means integrated and area wide planning (e.g. land use planning), the latter Sectoral (or specialized) planning aims to achieve sectoral objectives (e.g. educational planning, environmental planning). [246] Germany adopting a decentralized planning scheme with the planning authority at the municipal hierarchical tiers – that is known by local planning autonomy – with setting and alignment of the planning provision and aims to the ones at the higher hierarchical tires (state and regional). [247] The Objectives of federal / state / regional planning have to be integrated into municipal planning system and vice versa. While urban development planning should define local objectives, and preparatory land use planning and urban land use planning should be generated out of the objectives formulated within an urban development plan and have to be conform to federal / state / regional planning. [248] The hierarchy of the structure and identification of specific tasks and roles are done to a satisfactory degree of integrity and legality is stated clearly.

[246] Siedentop, S. (2007) *Regional Planning: Purpose and Objectives of Planning, Introduction to Regional Development Planning.* Regional Development Planning I

[247] Dieckhoff, R.S. (2009) *Planning Concepts in Germany*. City Planning Office State Capital Stuttgart, Department Urban Renewal Section of Urban Development. Urban planning II Lecture

[248] Bott, H. (2009) *Informal Planning Processes in Germany: Planning Concepts, Cooperative Planning and Citizen Participation*. Urban planning II Lecture.

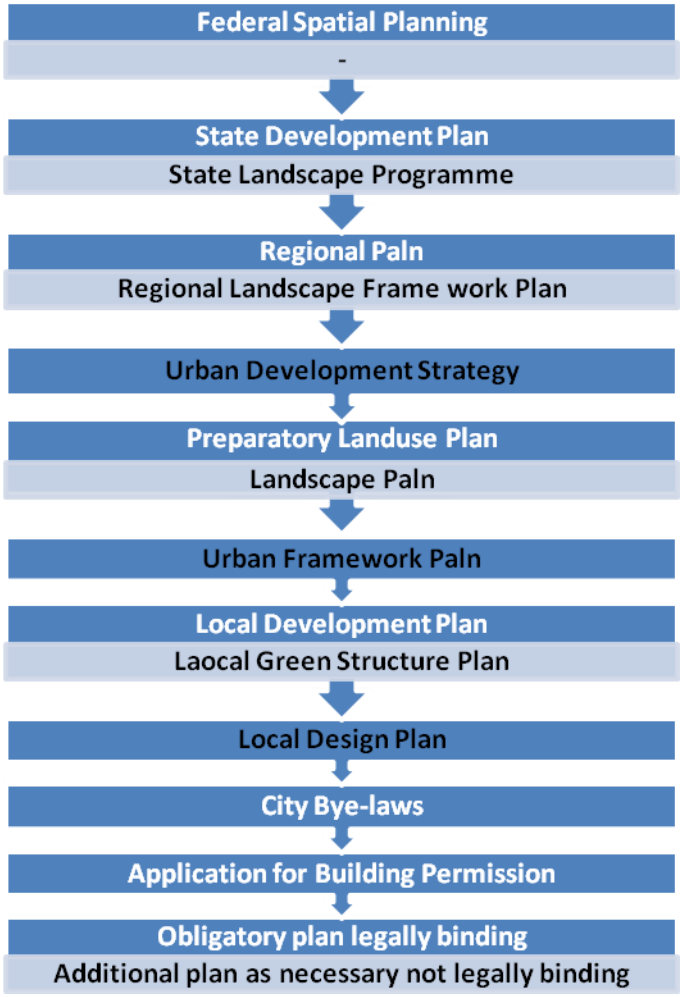


Figure 7.1: German Spatial Planning System according to the federal building code and to the state planning act.

Source: State Capital Stuttgart, Department of City planning and Urban Renewal.

Concerning the landscape planning system in Germany, "The system of integrated landscape planning includes the landscape plan and open-space control plan (on the level of zoning), the elements of the landscape master program (on the level of the Baden-Württemberg state development plan) and the landscape master plan (on the level of regional planning). Different manifestations of climate correspond to this scale as it refers to spatial planning. Elements for "green" planning that is also sensitive to local climate can be included at each of these levels, linking up to the implementation of an individual site plan" [249] .

Regional landscape Framework Plan, aims at maintaining and improving large-scale and interconnected structure of open spaces. "The importance of open spaces for productive land use, the water balance, fauna and flora and for the climate must be guaranteed or their function restored". It also includes supply for socio-economic usages of open spaces by with regards to their ecological function. [250]

[249] Ministry of Economy Baden-Württemberg in cooperation with Environmental Protection Department of Stuttgart. (2008). Climate Booklet for Urban Development Online.

[250] Siedentop, S. (2007) *Regional Planning: Purpose and Objectives of Planning, Introduction to Regional Development Planning.* Regional Development Planning I

Landscape Plan for City of Stuttgart, aims at nature protection and landscape conservation, in addition to municipal urban growth and land use planning. "The Landscape Plan supplements and counterbalances the provisions of the Land Use Plan and elaborates on landscape as a natural life resource. It covers both settled and non-settled areas, as well as areas zoned for development." The landscape plan centered around contemporary structure classes ("guiding functions: recreation, protected species and biotopes, and agriculture"). [251] The essential statement of the draft version is determining of zone with inadequate greeneries, the earmarking of green corridors within built structure and of zones of mitigation actions, allocation and cultivation. Accordingly the (Naturschutzgebiete) nature reserve is 1.362 ha 6.6% and (Landschaftsschutzgebiete) landscape conversation areas is 6.715 ha 32.4% of the total area[252]. It is worth to mention that the planning base is 10 years; its legal base is "Nature Protection State". The planning authority is 'The City of Stuttgart' and supervisory body is Municipal Council.

Local Green Structure Plan or "Open Space Plan" is at a lower tier, which is a non-formalized supplementary proposal. It specifies the local actions required to implement the goal of landscape protection and preservation of green space for recreational area, to enforce the goal of Landscape Plan. It is also monitoring and evaluating the condition of green space bases on ecological, social, economic and technical knowledge. The planning base is unlimited; its legal base is "Nature Protection State". The planning authority is the City of Stuttgart and regulatory group is the Municipal Council. [253]

7.3.2.2 Proposed Structure of Planning Hierarchy

The everlasting political conflict inside the country, the three preceding war and vague management policy that have been implemented shaped the history of the planning process in irregular way. The new government has not identified the structure of planning body yet. That is why Iraq Governmental structure is investigated. See Figure 7.2.

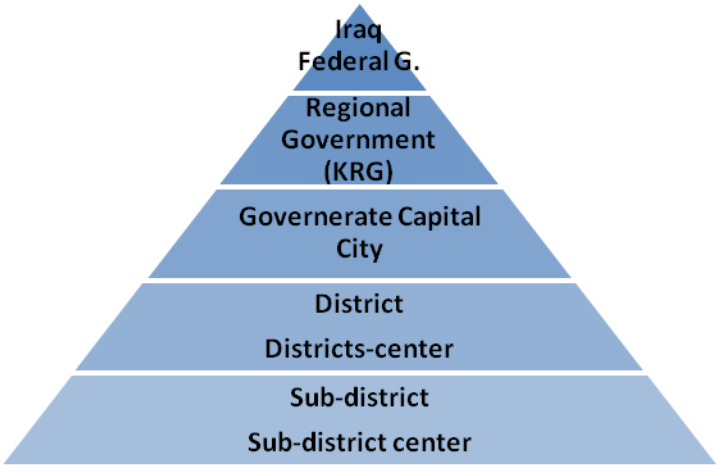


Figure 7.2: Hierarchical administrative division of Iraq.

[251] Department of City planning & Urban Renewal (2007) *Working paper on Urban Development Planning: Level of special planning in Stuttgart*.

[252] Dieckhoff, R.S. (2009) *Planning Concepts in Germany*. City Planning Office State Capital Stuttgart, Department Urban Renewal Section of Urban Development. Urban planning II Lecture

[253] Department of City planning & Urban Renewal (2007) *Working paper on Urban Development Planning: Level of special planning in Stuttgart*.

Source: Author 2010.

At a regional level, as well KRG is similar to a new country, which has only recently begun to plan its activities. It does not have a concrete hierarchy of planning body that has been drawn up over several decades, as is the case in developed countries. Nevertheless, according to planning practice at the related Ministries the following structure is derived

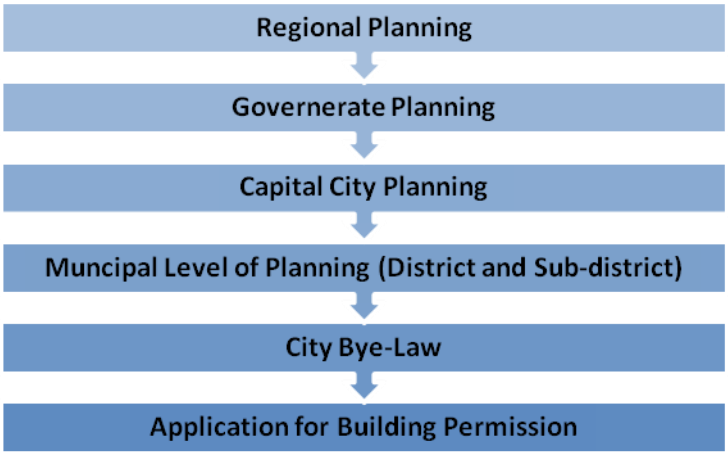


Figure 7.3: Hierarchical planning order in Kurdistan Region

Source: Author 2010.

Concerning landscape planning, there is no comprehensive landscape plan for the cities in CSR except for the case of Erbil city (capital city of KR) that they established the Landscape plane for the city the project called 'Green Belt of Erbil City'.

To establish the hierarchical planning bodies at National, Regional and Provincial (Governorate) and Municipal level, depending on academic background and with comprehensive overview about the Political and administrative hierarchy of Iraq, German model can be adopted for this purpose. With some difference of terminology of identifying the Tiers, since in Iraq there is KRG that is acting as counterpart of State political mass in a comparison to Germany. That is why the distinction in between terminology is quite important. Following the administrative hierarchy, the regional level is with the similar hierarchy of State level in Germany, and provincial level can be compared to regional level in Germany. Here is below the hierarchical proposed order of planning system in Iraq.

Figure 7.4: Proposed planning hierarchy for the Iraq

Source: Author, 2010

Establishing the structure can be adopted from the administrative hierarchy, but most importantly is identifying the role and extent of authority. Again German model can be taken as a base but cannot be adopted entirely, considering different government systems and different levels of development. That is why a general policy role is identified specifically for the topic of this study (GIP) without going in to detail.

In the national level, it is proposed that the planning body formulate regional and have a framework to integrate local plans. Also developing strategic plan for dealing with phenomena like; drought, dust storm, sand storm, natural reservation Area and Marsh land revival. Any plan at national level must totally aligned with Regional Strategies, and regional plan. At a metropolitan level (Municipal), one strong planning body should develop a compressive and detailed plan fitting to the general framework of provincial and regional plan.

7.3.3 Specific Implementation Strategy

At the regional level, a comprehensive GI Plan must be developed, setting the standard that should be adopted by municipalities. While this should aim conservation and management of natural resource, cultural resource and biotope, this can be achieved by robust protection and reservation

plan at a regional scale, and establishing framework to implement this plan by different related party Like Ministry of Agriculture and Water Resources, Ministry of Municipalities and Tourism and Ministry of Planning.

Developing a comprehensive GI Strategy Plan at a regional Level is of utmost priority. Embedding the GI approach into Local Master Plan Framework documents is an essential step. This would help the adoption and implementation of GI Strategy Plan through firstly land dedication and allocation for new GI and secondly as a tool to assist planners and developers in implementing GI plan. Regional Government should identify environmental hotspot then intervene immediately for improvement. At the same time identifying the potential and enhancing them by a robust strategy.

At a metropolitan level (Municipal), specialized planning body, targeting all related key stakeholders and interested parties in this domain, should develop a compressive and detailed landscape plan that fits to the general framework of provincial and regional GI plan. A comprehensive plan that reflect the multi-dimensional nature of GI, and the potential for multiple social, economic and environmental benefits, a wide range of other funding sources that could support investment in GI should be highlighted.

The Local Planning Authorities in each City need to assign a explicit and steady planning agenda for the formation, management and maintenance of GI network (green spaces and urban forest in particular and natural landscape in general). This framework should include general policies for green spaces and urban forest, along with proposals for specific outstanding areas.

At the local or municipal level, planning urban green, designing management and maintenance should be their responsibility. While for Landscape Plan as a whole other parties like, Ministry of Agriculture, Orchards and forestry department and Tourism directorate can share implementation management and maintenance work. Particularly, for the CSC different strategy, but at the same time well integrated, must be adopted, since the CSC facing unique problems. In this sense, built up area (addressing area with high shortage of green space), surrounding landscape (conservation and reforestation strategy) and newly developed area (adopting new Green space ratio, and planning more connected and systematic green network) must be of great interest with different strategy of management.

7.4 Recommendations

- **Legislation**

Most of the laws and regulations existing in the Kurdistan Region and Iraq are out dated or not well coordinated. These have to be reviewed and updated to suit current situation and have successful implementation of GIP in the area. The following specific recommendations are made in this respect.

To formulate a water framework and watershed management, it has become more common around the world for whole river catchments systems to be managed by a single body in one country, and by a group of countries establishing one cooperation (e.g. a mechanism like river co-operative organization in Germany to manage and control all groups either directly using water or affecting its quality). A similar mechanism can be of great importance for the water use and improvement of quality and quantity of Tigris and Euphrates rivers. In Iraq, the two main rivers originate outside the country. Thus, requiring international cooperation, that is why a new Joint Technical Committee on Regional Waters has to be founded between all countries of Euphrates and Tigris basin (Turkey, Iraq Iran and Syria) under the shadow of climate change and new hydrological projects by different parties in a way granting the right of countries downstream.

The present Forest Law in Iraq was promulgated long ago, but never been updated or put in to action. The activation and update of the Forest Law is quite important at a current state of water scarcity and desertification problem at a national level. So the legislation of new watershed directive should be based on the three basic policies (protection, enhancement and reforestation). Most importantly in the course of this investigation, map of most effective area for Reforestation of watershed area has been developed.

- **Watershed Enchantment**

USDA Forest Service identified three main policy for managing Watershed Forestry namely protection enhancement, reforestation. The protection of Watershed Forestry from human encroachment and land development are conservation of the existing forest and shrub land in the CSR. Secondly, the enhancement of health, condition, and function of forest (natural or urban) fragments are achieved through a comprehensive and integrated forest management. Final goal is the Reforestation of open land through natural regeneration or plantings in the aim to regain some of the functions and benefits of forest cover in watershed areas.

Also Policy for reviving Karez resource by planting tree at the infiltration area and preventing development is recommended.

- **Developing Hierarchical Planning Structure**

Hierarchical order of planning, a well definition of authorities regarding Bottom up, and Top down concept in planning, (Federal, regional, Governmental, and Municipality level), to develop a hierarchical planning body that integrate and join forth all the key Sector Stakeholders at a present political and administrative radical change of the country's ruling system make this mission difficult. However, it is of utmost priority that KRG have to adopt this approach and work on both level. The first level is to integrate within the national and international system. The second and most important is to establish a well-structured planning body that guaranty the integration of all parties and policies and particularly natural resource management.

- **Use of Modern Planning Techniques**

In addition to the proposed hierarchical system of planning at the national level in Iraq and at the study area level the Kurdistan Region and Sulaimaniyah City is further recommended that modern practices to be adopted for the successful implementation of GIP. This includes; Creation of database that makes the municipalities and planner get benefits of the application of GIS in planning and decision making process and adopt new planning ideas related to GI.

The regional government (KRG) should set different program adopting or even imitating the once that are launched by other developed countries like Great Britain, Germany etc. For example, "How to program to promote 'Cleaner, Safer, Greener' communities" that lunched lately by Britain Government.

- **Establishing Planning Commission and Research Center**

The crucial and important task for KRG is to set up a 'Sustainable Development Commission' and formulate and Sustainable Development Plan'; this will guarantee the sustainable development and integration of similar and conflicted interested party all together. It will serve all related field of natural, economical and urban growth development.

Establishing a department in Scientific Research Center in Universities of the Kurdistan Region, to deal with multi-functional benefit of priority projects in allocated areas is necessary. Moreover, accomplishing further research related to adaptation to climate change through GI Concept.

It is strongly recommended to establish a GI Supervision Team as a Regional committee to co-ordinate implementation of GI in the Cities and providing funding and delivery of the key projects. In addition, it is so important to establish a site-specific baseline then continues monitoring and assessment process, since without that any developed plan or strategy may not be durable.

In conclusion, cooperative methods to GIP can integrate several distinct policy areas, counting "natural resource management, nature conservation, landscape, recreation and public health".

- **Public Awareness**

Raise awareness of the GI Importance through a public launch, Introducing the importance and awareness of key stakeholders and planners about up to date terminology and assessment like Ecological footprints, EPI, Carbon foot print etc. Policy makers and citizens should recognize the importance of natural resources and working landscapes to the ecological and economic vitality of the Region and its communities. Environmental awareness certainly is a scope, which only can be handled by political institutions and public media.

Lack of political support and leadership can equally be overcome by environmental awareness of decision makers and changing their priorities from short term to long-term understanding. This should be reinforced by social awareness for protecting preserving and Living with nature

Promote sustainable development across Government – providing balanced policy and resource attention between economic, social and environmental priorities is central to this theme and relates comprehensively to the need for improved planning and delivery of GI.

- **Integration of Green Infrastructure Plan in Planning System**

It is strongly recommended that landscape dimension integrated in planning system at all spatial planning level, particularly at a city's level. Erbil City Landscape Plan can be taken as a model for all other cities. It is important for municipalities to develop comprehensive spatial strategies for the GI to preserve existing green space and create new green space such that a functional network is formed. Also infill development could be restricted in buildup area particularly at plot level. GI program must be based on adopting cities to climate change and mitigating the city's systemic issue. The plan should reflect the multi functionality and comprehensive understanding of city's climate.

- **Introducing New Typology of Green Infrastructure**

In the environmentally overburden buildup area, introducing new typology like green roof and vertical garden is recommended as adaptation strategy and mitigation measure to address the shortage of green in those areas. Also when possible, the street side area ought to be landscaped to ensure air filtration provision.

Introducing Green Space Ratio in newly developed area, with a radical change in planning concept of urban green space from small isolated pocket of green to integrated and connected network f green in and outside the city.

- **Typology of Vegetation**

Changing of pattern and typology of greening is strongly recommended due to climate and urbanization effect. Mature trees will provide more ecosystem services (decreasing surface temperature by providing shade and intercepting rainfall). In addition, during drought they could deliver a cooling function for longer than grass that will dry off quicker. Another possible solution would be introduction of drought-resistant planting. This can be achieved by changing type to green, which is more economical in terms of management, providing more ecosystem services (decreasing surface runoff, temperature, and higher Carbon sequestration capacity) in a comparison to lawn, particularly regarding and tree species, which are more resilient to drought.

The barrier due to the soil formation (Limestone rocks laminated with heavy textured soils (salty clay soil)) at the up part of mountains area, can be diverse to a potential of reforesting and new orchards areas in near future through proper management. As it has been pointed out and proven by local researches that this area is a harsh ecosystem forming suitable biotope for wild Almond, which is indigenous and wide spread natural vegetation in the mountainous region in CSR that can be enhanced and will convert those rocky or shallow land to productive orchards.

- **Environmental Impact Assessments and Audits**

Environmental Impact Assessment enhancement, this should cover all projects and planning process. In addition, the monitoring technique and phase is strongly recommended in the case of Iraq.

The EIA process must be conducted by all industrial activities namely `oil boring, cement and asphalt production, construction martial mining and etc.`. The set of robust environmental rules - that regulate and limit contaminating the surrounding environment, along with the damage of natural habitats alongside water features and plain- must govern all existing and planned industrial facilities. In addition, other activities that are may have negative impacts to the environment like fishing and hunting should be regulated.

- **Innovative Water Storage Mechanisms**

During the periods of water shortages, and areas that facing drought problem a clever water mechanism should be adopted namely “rainwater harvesting, the re-use of grey water, making use of water in rising aquifers under cities where present, and floodwater storage,” Unless the irrigation demand will made a conflict with water shortage problem. [254]

7.5 Conclusion

Due to climate change effect, Iraq is experiencing, drought, water scarcity, desertification and overheating problem. Water scarcity problem at a national level enhances the CSR footprint in managing watershed as a policy for mitigation and adaptation. The enhancement of watershed areas is achieved by increasing forest cover. Since the whole area of the CSR is a basin of Tigris River and its main turbidities, so reforestation at main stream accumulation will have a positive impact in recharging surface and ground water. That is why by applying spatial analysis tool from Arc GIS 9.3

[254] Gill, S.E.; Handley, J.F.; Ennos, A.R. & Pauleit, S. (2007) *Climate change and cities Adapting Cities for Climate Change: The Role of the Green Infrastructure*. pp(115-133).

software areas with more stream accumulation have been identified. Consequently, reforestation of those areas will be more influential in enhancing watershed.

However, the CSR is having to experience different effect of climate change which is an increase in temperature, decrease or stable of precipitation rate. Also, the ecosystem damage and species loss are anticipated to be most substantial in high land region where flora availability and distribution is probable to move to higher altitudes, that is why wildlife at the SE part of the CSR that characterized by the hotter environment will be highly vulnerable to damage namely Maidan Area.

The CSR is proved to have a rich natural and cultural resource footprint, to manage each resource individually is not feasible and practical. That is why integrating of the resource that needs to be managed can be incorporated through a creation of the multifunctional network, which serves the preservation, conservation and watershed enhancement policy, along with biodiversity enhancement. This conducted by the author through proposing multifunctional GI Plan by introducing corridor to connect the Key Biodiversity Area and at the same time, trying to maximize the benefit outcome by preserving the existing cultural and natural resource.

As well the proposed network can diverse land limitation in use due to steep slope, erosion, soil texture and rocky surface to potential through proper management planning. In this regard, the proposed (network) Corridor covers 33.3% and Core cover 53.6% of areas with specified limitation in use. Besides environmental and recource management benefit the plan's outcome will enhance the touristic footprint of CSR that will serve social and economical function as well.

The CSC is also vulnerable to flood risk due to the geomorphologic setting, the pattern of development on the natural cores of water pass way (Wadis), technical derange system problem and a high percentage of surface capping. Also due to urbanization and climate change effect, by 2020 the urban temperature of CSC will be higher than its surrounding open land by 1.9-4.1 °C. Since the temperature of CSC is higher by (1.3-2 °C) and a further increase of (0.6-2.1 °C) is expected by 2020 due to climate change, that is why adapting to temperature increase is the most site specific issue that local government and planner must deal with.

The emission calculation has been carried out to car induced pollutants such as Nitrogen oxides NOx; PM10, Carbon Monoxide (CO), Benzene and Sulphur dioxide (SO_2) and, the pollutants that have a direct effect on human health, at 11 sections. All results, except for few, show pollution rate exceeding the threshold; moreover the number of times that exceed the threshold is far beyond standard as well.

Hence CSC is a thermally polluted facing problem of surface runoff management also air pollution rate is high, thus regardless of dust pollution. Accordingly, measures and adaptation strategy should be implemented. The author conducted implementation of GIP concept the finding were:

At a landscape scale existing GI percent is 8%, the expected GI according to new Master plan is expected to increase to 15%, while by the proposed GI Plan it will be rise to 23%.

After analyzing the CSC, it is proved that urban green area in term of quantity, quality and connectivity is far under the standard. The percent of green area is 5.26% in urban area in a comparison to the minimum standard by Time Saver is 10.4%. Also, the share of the green space is ranging from 0.01 to 9.85 m^2/capita (at identified section) against minimum limit 10.2 m^2/capita by Time Saver. Accordingly, urban green portion is positively related to the availability of open space and inversely correlated with built-up density. Moreover by applying buffer analysis more than 64%

of the area inside 60m Ring road is not connective to required green area. Also S and E part of the CSC shows poor performance than the rest part.

The urban green planning concept consists of the isolated patch of small size without connections. That is why a network based on connecting existing GI to planned and proposed GI typology is designed, in order to form connected and integrated network in and around the CSC.

Development and constructional measures on the hillsides particularly Goizah hillside must be set and restricted. In the new developed area and restoration part, it is most cost effective time to integrate proper design and technological measures, to facilitate the realization of the proposal's potential in adapting to global warming and climate change.

Implementing Green belt around CSC concluded to be the best solution and alternative to enhance climatic condition, preserve fertile land around the city, preserve the climatic important area like the hillside, prevent sprawl also it will act as a buffer between the existing city and surrounding mountain. Moreover, it will enhance infiltration capacity and reduce the damage that causes due to the unstable use of groundwater.

Increasing conventional green space is not feasible in existing buildup area that is why the alternative solution for increasing green will be Greening the roof and Vertical garden. Never the less due to the increase of the building mass in those areas of rehabilitation in City Center it is a must that areas should be dedicated to Green space.

Applying ecological indicators (hydrology and carbon storage and sequestration), It has been concluded that better urban climate directly proportional to the percentage of urban green areas.

By implementing the GI plan, Carbon Sequestration capacity will rise since the total area covered by trees will be increased from 950 ha to 4600 ha, according to designed typology.

By increasing 17.5 % of the green area mainly green roof in City Center, a percentage of pervious area will increase from 2-3.8% to 5-15%, and carbon storage capacity will rise from 0-0.01 tonne/ ha to 0.01-0.025 tonnes/ ha, thus regardless of temperature reduction factor that is estimated for around 2 ^{o}C. Managing surface runoff cannot be overcome totally through increasing green area only (be it conventional or none). That is why this should be mixed with the water retention and other management technique.

By implementing GIP, a considerable improvement of ecological performance is obtained as it has mapped, but not all the part of the city examining the same degree of improvement. For instance, the E and S part of the city a recognizable improvement is achieved while at some neighborhood namely 110, 112, 114, 116, 219 and 215, no change recorded unless the green belt is implemented as it designed starting from the existing limit of 60m ring road.

Considering the ecological performance indicator, the author acknowledges the shortcoming of result particularly in applying energy exchange model, due to the limitation of data and time. Depending on GIS analysis tool the other indicator shows clear change due to proposed green concept.

It can be concluded by saying integration at spatial and institutional level is one of the fundaments, and GIP approaches providing a good guide to achieve that. Also to plan a green concept with targeted ecosystem function that identifies specific typology of green, vegetation type and most importantly where it has most benefit outcome can be achieved through it.

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Appendix A

List of interviews

The following includes information about the individuals that have been interviewed in the site visit to CSR in Iraq on May 2010.

General Directorate of Environment,
Erbil Office: Mr. Jamal, A. General Manager. He provided documents about pollution state.
Sulaimaniyah Office: Mrs. Muhabad M., head of EIA department. She provided information about environmental state in CSC, by hardcopy.

JHIC
Miss Bahar Mahmud, GIS coordinator. She provided soft data about CSR and Iraq administrative border also other data collected for National Geospatial Agency (NGA).

Ministry of High Education and Scientific Research,
University of Salahaddin, Main Library: Hard copy of related PhD and Master Thesis.
Sulaimany University, College of Agriculture: Dr. Ahmed Ibrahim, provided maps and hard copy data about CSR and CSC.
Sulaimany University, Human Sciences College: Dr. Jamil Jalal and Mr. Soran M. provided PhD and Master Thesis with .pdf format.

Ministry of Interior,
Kurdistan Statistic Office: Mr. Mahmud Abdulla, General Manager. He provided hard copy data about population of neighborhood in Sulaimaniyah City.
Traffic General Directorate: Statistical data about vehicle number have been provided.

Ministry of Municipality,
GIS and Planning Department in Erbil: Mr. Khalid Abd., General Manager. He provided data about Erbil city master plan and the hierarchical frame of planning system.
Municipality of Sulaymani City: Mr. Khasraw Kamal, Mayor of Sulaimani City. He provided with coordination with Master Plan and GIS department the soft data about the new master plan.

Ministry of Transportation and Communication, Sulaimanya Meteorology Station,
Mr. Azad M., technical recorder. He provided metrological data in softcopy format.

Municipality of Kirkuk City,
Mr. Jamal Ali, Mayor of Kirkuk City He provided the hard copy of Kirkuk City Mater Plan.

Online Interviews

Nature Iraq,

Miss Anna Sophia Bachmann, Program Manager in Nature Iraq, Sulaimaniyah, Kurdistan Iraq. She provided the soft copy of "Key Biodiversity Survey of Kurdistan, Northern Iraq: Site Review – 2009 Survey" via email. She provided useful information about the availability of data about the CSC. October 15 2010.

UNDP-Iraq,

Mr. Paal Aarsaether, Chief, Communications and External Relations of UNDP-Iraq, Amman, Jordan, confirmed the lack of data through Mr. Rob Duys, PM interim Climate Change, Energy and Natural Resource Management United Nations Development Programme. He covered answering the question about 'climate change in Iraq and particularly CSR' by "As discussed – the unfortunate side effect from the wars in Iraq is the lack of hard data. We hope that eventually the national communication to the UNFCCC to start in 2011 will provide the required data. The conference in July was a stock taking exercise and exactly the below questions are then being addressed". Then added "For scenario building on drought and desertification - Iraq signed up to the UNCCD just 2 months ago. Again very little is available".

Appendix B

Iraq Map

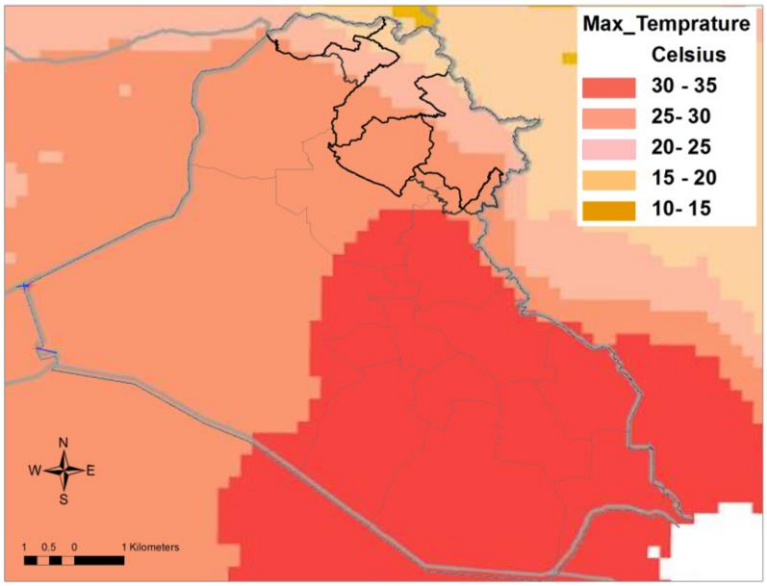


Figure B.1: Iraq mean annual maximum temperature

Source: http://www.wunderground.com

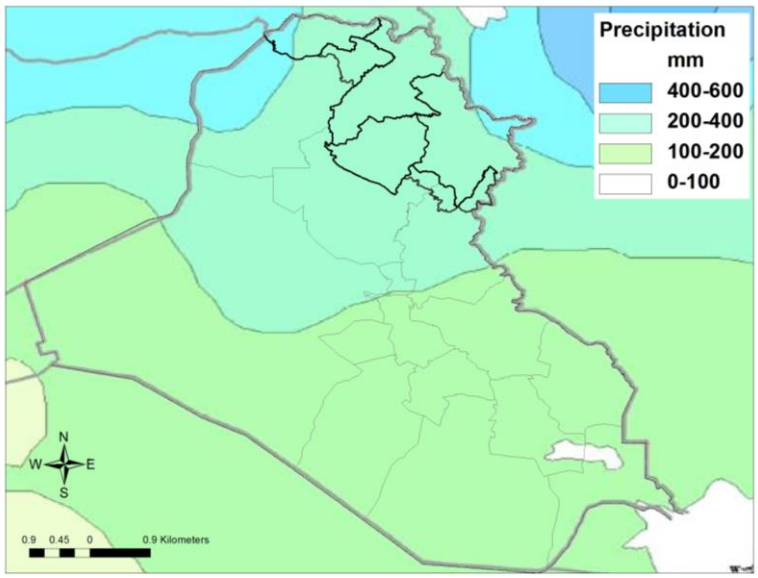


Figure B.2: Iraq mean annual precipitation

Source: http://www.fao.org/

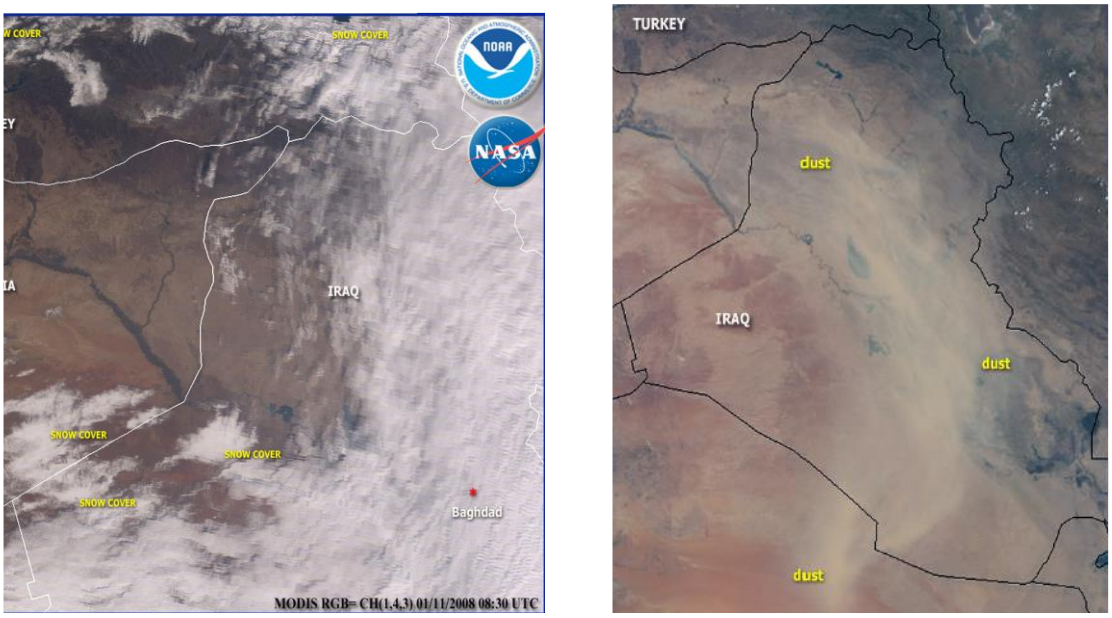


Figure B.3: Snow storm (L) and Dust storm (R) across Iraq

Source: NOAA/ NASA.

The first satellite image shows extremely rare snow that fell across parts of the Middle East countries of Syria and Iraq. The second satellite image is a Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite that shows thick dust with combination of small bumps and curving waves over western and northwestern part of Iraq.

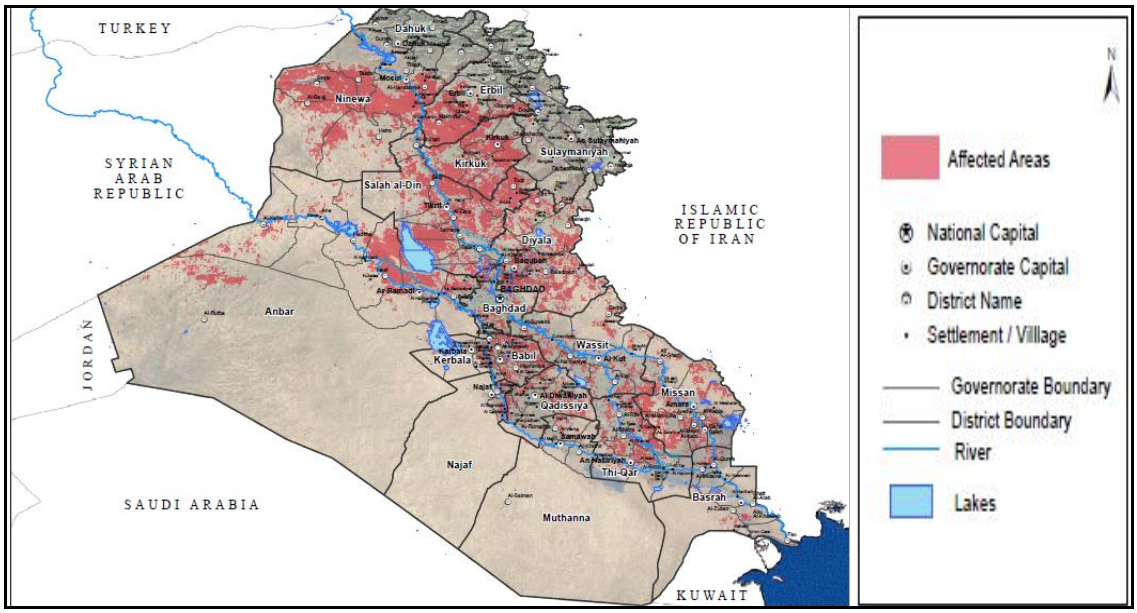


Figure B.4: Iraq - areas affected by drought in 2 consecutive years 2008 – 2009

Source: www.iauiraq.org

Appendix C
Literature review

Table C.1: Function of Green Infrastructure planning at different spatial scale

Source: C Davies, R MacFarlane, C McGloin, M Roe (2008).

Scale	Examples of Green Infrastructure	Function of Green Infrastructure Planning
Regional (NE Region)	Nationally designated sites (e.g. NNRs, cSACs, SSSIs, National Parks, AONBs, Heritage Coasts) Major river corridors (e.g. Tyne, Tees, Wear) Major recreational and amenity sites Long distance footpaths (e.g. Pennine Way, Hadrian's Wall Path) National Cycle Network	Strategic environmental capital can be subdivided into natural resources (e.g. carbon sinks, water framework and habitat framework) and cultural resources (e.g. landscape, amenity and recreation such as National Parks and Heritage Coasts). The most significant, usually designated, areas, sites and routes of both of these resources are identified as being the regional green infrastructure. At this level the emphasis is on the identification of the highest priority elements and routes and the establishment of strategic priorities for GI development. Prescriptive details on how areas are to be enhanced or routes to be developed would be inappropriate at this level.
Sub Regional / County	Significant or extensive public parks and gardens such as Country Parks or Forest Parks Local Nature Reserves Significant river corridors (e.g. River Coquet) Significant recreational routes (e.g. Cleveland Way) Significant coastal beaches (e.g. Druridge Bay)	At the sub-regional level the emphasis in GI planning is in identifying those elements which have the potential to qualitatively enhance the area's environment as a whole (including the perception of that environment) and where the infrastructure may be significantly strengthened by higher level initiatives that span local authority boundaries.
Borough or District	Public parks and gardens Other river corridors Public Rights of Way and Greenways Local cycle routes Playing fields Informal green spaces Accessible woodland Reservoirs, water bodies and wetlands Other coastal access areas	At this level GI planning is fundamentally about providing (a) suitable and sufficient green spaces for recreation, amenity and conservation purposes, and (b) a coherent infrastructure of green and green-grey links that provide routes and pathways for multiple purposes. A GI plan should focus on the infrastructure of the area as a whole and how links can provide both local benefit, and integrate with higher tier GI priorities and plans and also those of neighboring districts or boroughs. At this level opportunities to extend GI through new, perhaps unforeseen, opportunities should be accommodated, so a degree of flexibility to respond to such opportunities is essential.

Neighborhood	Street scene (e.g. trees, flower beds) Domestic gardens Allotments and Cemeteries Small water bodies and streams Permissive rights of way Institutional or private grounds Brownfield sites with GI potential Productive farm and forest land with GI potential	At a neighborhood level formal GI plans may not be created, but the essential principle is that the cumulative effect of many highly localized initiatives such as street tree establishment / management or the encouragement of positive use of private gardens may be considerable. In this respect the enhancement of qualities of life, place and environment at the local or neighborhood level is a partnership between private individuals and public authorities, to a large degree, although not exclusively, on privately held land.

Key benefit, primary contributors, key outcomes, derived from (ECOTEC, (2006)), with addition of some part.

Table C.2: Key benefit and key outcomes of Green Infrastructure Planning

Source: ECOTEC, (2006).

Key benefit	Primary contributors	Key Outcomes
Economical Benefits		
Enhanced economic regeneration	Greenspace providing a setting for investment. Greenspace providing an improved Quality of Place/higher Quality of Life. Release of new sites for development under GI framework Diversification of working land with economic value New economic activity related to tourism and leisure, woodland produce, conservation, education and stewardship. Renewable energy generation	Improved visual appeal and amenity leading to greater tourism and leisure expenditure. An improved offer of the City Region to inward investors in particular. More employment opportunities and opportunity for diversification of local economies. Improve staff morale and retention Higher rental values reflecting increased neighborhood desirability for workspace. Higher land values Sustainable food production.
	Increasing previous pavement type Natural storm water management way. Other related projects of water supply and waste water treatment.	Save capital costs associated with grey infrastructure. Like paving, digging big tunnels and centralized storm water ponds, treatment plants, pumping stations, pipes and etc…
Social Benefits		
Improved Quality of Place, enhanced Quality of Life.	New and improved greenways, rights of way and improved linkages between sites providing a network for sustainable transport. New and improved parks and recreational areas. Improved multifunctionality of green spaces. New 'open access' land Improved public transport	Improved health and well-being through active lifestyles and places to relax. Greater opportunity for formal and informal play and recreation. Improved visual amenity. Improved community activity, improved community spirit. Higher property values recognizing increased desirability of neighborhoods.

	Improved visitor information and interpretation facilities. 'Gateways' to the countryside	
Improved health and well-being	Access to greenspace for formal and informal sport and recreation. Access to greenspace for leisure purposes Trees and woodland conservation and planting help to improve air quality. New opportunities for local farmed produce –orchards, allotments, farm diversification.	Healthier workforce. Fewer demands on health services. Improved health bringing people off incapacity benefit and into work. Reputation as healthy place to live – improved Quality of Place reality and perception.
Conserved cultural heritage	Conservation of historic and archaeological sites. Conservation and regeneration of bio physical assets e.g. waterways, ancient and seminatural woodlands	Reconnecting communities with their landscape. Recreating visual identity beyond 'bricks and mortar'. Pride in place Greater identification with local landscapes.
Environmental Benefits		
Improved biodiversity	Habitat creation and conservation 'Soft' flood defences and SUDS Linked natural sites – wildlife corridor creation and conservation. Improved water management Increased interest in conservation through education and awareness raising.	Educational resource Improved water quality – improved habitats Green tourism – growth in employment opportunities Conservation – growth in employment and training.
Increased contribution to addressing climate change	New woodland planting Street trees Increased greenspace coverage Renewable energy production	Microclimate control – shade in summer, reduce wind effects on homes and workplaces. Air conditioning – reducing overheating of buildup areas. Reduced carbon emissions. Allowing species to migrate and adapt to the effects of climate change.
Flood prevention and water management.	Greenspace by rivers function as recreational and natural greenspace but also provides flood storage/capacity to prevent flooding. 'Soft' flood defences providing space for floodwater, e.g. new wetlands Sustainable Urban Drainage (SUDS) systems. Tree and woodland canopy help to regulate runoff.	Less flooding, reduced loss of property, less disruption to economies, fewer disincentives to investment. Natural greenspace conservation and management. Habitat creation.
Air and noise pollution control	Tree and woodland conservation and planting. Increased greenspace coverage Strategic planting for noise/air pollution alleviation.	Improved visual amenity – attractive setting for investment. Trees and greenspace act as a carbon sink. Improved quality of life - benefits to health of cleaner air and noise reduction.
Sustaina	New woodland planting	Increased energy efficiency by decreasing the

ble resource manage ment *	Street trees Increasing the amount of pervious ground cover, by increasing green space coverage Increasing natural swales ,ponds and etc..	energy needed for heating and cooling Cleaner water Cleaner air Source water protection Enhanced water supplies Enhanced groundwater recharge Reducing point source pollution to receiving water body by reducing sewer overflow events, Storm water pollutant reductions Providing space to grow food using sustainable methods.
Planning for Growth		
Providin g framewo rk for future develop ment**	Greenbelt creation and protection Expanding network of green and open space in new developed area.	Creating a plan for future growth with ensuring that significant natural resources will be preserved. Reduce opposition to new development. Preventing urban sprawl Defining urban Structure Increasing community livability
Increasin g cultural, amenity and aesthetic value (Aouther)	Connecting existing green space by creating network. Increased green space coverage Street trees Connecting urban green space to natural and semi-natural green outside urban areas by creating links and corridors. Increasing urban forest	Increasing community livability Give local character and Identity Contribute to the aesthetic, historical and cultural identity of the city. Safeguard and enhance natural and historic assets between, in and around Communities Provide natural balance between built environment and natural and/or semi-natural environment. Restoration of constructed town scape. Landscape variation through different colors, textures, form and density of plants.

*http://www.epa.gov/npdes/pubs/gi_action_strategy.pdf & http://cfpub.epa.gov/npdes/home.cfm?program_id=298. ** (Mark A. Benedict and et al (2002))

Table C.3: Projections for extreme weather events based on observed late 20th century trends.

Source: IPCC AR4 Working Group 1, Summary for Policymakers, 2007.

Phenomenon and direction of trend	**Likelihood of future trends based on projections for 21st century using SRES scenarios**	**Example of major projected impacts for industry, settlement and society**
Warmer and fewer cold days and nights over most land areas	Virtually certain	Reduced energy demand for heating: increased demand for cooling, declining air quality in cities..
Warmer and more frequent hot days and nights over most land areas	Virtually certain	Reduction of quality of life for people in warm areas without appropriate housing: impacts on the elderly, very young and

		poor.
Warmer spells/ heat waves. Frequently (or proportion of total rainfall from heavy fails) increase over most areas.	Very likely	Disruption of settlement, transport and societies due to flooding: pressures on urban and rural infrastructure: loss of property.
Area affected by droughts increases	Likely	Water shortages…reduce hydro generation, potential for population migration.
Intense tropical cyclone activity increases	Likely	Distribution by flood and high winds, loss of insurance population migration, loss of property.
Increased incidence of extreme high sea level.	Likely	Costs of coastal protection v. relation, loss of insurance, population migration, loss of property.

*Virtually certain are events with a 99% probability of occurrence while Very likely are events with 95% probability of occurrence.

Table C.4: Ecosystem and climatic services of different GI typology

Source: Author, 2010.

Type	Ecosystem and Climatic Services
Roof-garden, Green roof	-positive thermal effects and thermal performance of building - Reduction of temperature extremes throughout the year and urban heat island. To 20°C to 25°C in summer and slightly blew zero in winter. -Reduction of temp. fluctuation from 100 °C to 30°C in a comparison to concrete slab - Reduction of amount of participated water that have to be drainage to 30% -Low dust filtration effect. Depending on planting communities
	-Enhance biodiversity, provide amenity for residents -provide opportunities to grow food and improve appearance -Increase living space.
Vertical gardens	-Improvement of heat insulation via an air cushion between the building and its surroundings -Decrease in heat loss via wind braking -Decrease in heat loss via changes in radiation (i.e. sunlight) conditions -Transformation of wind energy to heat -Cooling effect via evaporation, absorption and reflection of sunshine by leaves -Production of humidity via evaporation -Protection of the façade from strong temperatures, UV rays, and hard rains -Improve appearance.
Street trees	-Reduction of ambient heating thus serves to balance out overheated city structures - Large-crown trees and their corresponding shade create comfortably-shaded spaces - High dust filtration effect. - High Wind protection effect that may diverse the pollution removal effect by wind -High atheistic value.
Linear green buffer	-Reduction of ambient heating - High dust filtration effect - High Wind protection effect

	-Sound barrier -High atheistic value - Enhance biodiversity, provide amenity for residents.
Conventional garden	-Lawn and grass land use as components of cold-air production areas. -Moderate to good dust filtration effect.
	-Enhance biodiversity, provide amenity for residents, provide opportunities to grow food and improve appearance.
Greenways	-Reduction of ambient heating thus serves to balance out overheated city structures. - Large-crown trees and their corresponding shade create comfortably-shaded spaces. - Protect natural habitats -Cultural and recreational value and aesthetic value.
Green Corridors	-Reserving fresh air corridors -Climate-regulating function - Improve water quality and reduce the impacts of flooding in floodplain areas -Enhance biodiversity, provide amenity for residents.
Agricultural and Meadow	-Producing10 to 12 m^3 of cold air per square meter per hour -Cold air layer 12 meters thick can arise in the span of an hour -Food production
Urban Forest	-Reduction of ambient heating thus serves to balance out overheated city structures - Improve water quality and reduce the impacts of flooding in floodplain areas -Outside of built-up areas, forests create hindrances for cold air flow -High cooling effect for large forest according to position - High dust filtration effect -High wind protection effect -Act as Carbon sink
	- Habitat for wildlife -provide opportunities to grow food -Enhance recreation and provide amenity for residents.

*Ministry of Economy Baden-Württemberg in cooperation with Environmental Protection Department of Stuttgart. (2008). Climate Booklet for Urban Development.

To quantitatively describe the vegetation potential of a land area various attempts have been made. The "phyto measurement number (PMZ)" method by SCHERER (1973) allows the principle of the “plant-quantity calculation (phyto measures)” in a hierarchical order. “The allocation of "phyto measures" per square meter of undeveloped property area to the specified vegetation forms should concurrently describe their efficiency relative to various bio-ecologic components, including dust filtration effect, evaporation, wind protection, and shade provision.” See table C.5.

Table C.5: Climatic service and PMZ of different type of vegetation

Source: Author, 2010

Type of vegetation	**Phyto measurement number (PMZ)**	**Climatic Services**				
		Ventilation effect	**Dust filtration effect.**	**Cooling effect**	**Wind protection**	**Shade provision**
Open ground	0,5	good	No effect	low	No effect	No effect
Lawn	1,0	high	No effect	Very high	Very low	No effect
Meadow	1,5	high	moderate	high	moderate	low
Shrub to 1 m height	2,0	good	Good	Good	moderate	low
Small wood to 1 m height	3,0	moderate	Good	Good	moderate	low
Hedge to 2 m height	4,0	moderate	Good	Good		moderate
Needle wood to 3 m height	4,5	low	High	moderate	Good hindrance to airflow	Good
Leaves wood to 3 m height	5,0	low	High	moderate	Good hindrance to airflow	high
Needle wood 3 m to 5 m height	6,0	Very low	Very high	low	Good hindrance to airflow	Good
Leaves wood 3 m to 5 m height	7,0	Very low	Very high	low	Very Good hindrance to airflow	Very high
Coniferous trees to 10 m height	8,0	No effect	Very high	low	Very Good hindrance to airflow	Very high
Deciduous trees to 10 m height	9,0	No effect	Very high	low	Good hindrance to airflow	Very high

*Ministry of Economy Baden-Württemberg in cooperation with Environmental Protection Department of Stuttgart. (2008). Climate Booklet for Urban Development

Appendix D

List of wildlife and birds seen on the KBA Surveys for Kurdistan, Northern Iraq in 2009

Table D.1: Wildlife observations for the 2009 survey

Source: Nature Iraq, 2009.

Site Name (Site Code)	Species	Conservation Status	Reports or Observed
Maidan Area (S21)	Goitered gazelle (*Gazella subgutturosa*)	VU	Reported
Dukan (S2)	Euphrates Soft-shell Turtle (*Rafetus euphraticus*)	EN	Observed
Qara Dagh (S11)	Spur-Thighed Tortoise (*Testudo graeca*)	VU	Observed
De Lezha (S23)	Spur-Thighed Tortoise (*Testudo graeca*)	VU	Observed
Homar Qawm (S24)	Spur-Thighed Tortoise (*Testudo graeca*)	VU	Observed
Barzan Area (E8)	Wild Goats (*Capra aegagrus*)	VU	Observed
Dure (D16)	Zagrosian Lizard (*Timon princeps kurdistanicus*)	Semi-endemic	Observed

Table D.2: List of birds seen on the KBA surveys for Kurdistan, Northern Iraq in 2009

Source: Nature Iraq, 2009.

Order	Common Name	Latin Name	Conservation Status
GALLIFORMES	Chukar Partridge	*Alectoris chukar*	
GALLIFORMES	See-see Partridge	*Ammoperdix griseogularis*	
GALLIFORMES	Black Francolin	*Francolinus francolinus*	
GALLIFORMES	Common Quail	*Coturnix coturnix*	
ANSERIFORMES	Eastern Greylag Goose	*Anser anser rubrirostris*	
ANSERIFORMES	Greater White-fronted Goose	*Anser albifrons*	
ANSERIFORMES	Lesser White-fronted Goose	*Anser erythropus*	Globally Threatened (GT), Conservation Concern (CC)
ANSERIFORMES	Common Shelduck	*Tadorna tadorna*	
ANSERIFORMES	Ruddy Shelduck	*Tadorna ferruginea*	
ANSERIFORMES	Eurasian Wigeon	*Anas penelope*	
ANSERIFORMES	Mallard	*Anas platyrhynchos*	
ANSERIFORMES	Northern Shoveler	*Anas clypeata*	
ANSERIFORMES	Northern Shoveler	*Anas clypeata*	
ANSERIFORMES	Garganey	*Anas querquedula*	
ANSERIFORMES	Eurasian Teal	*Anas crecca*	
ANSERIFORMES	Marbled Duck	*Marmaronetta angustirostris*	Conservation Concern (CC)

Order	Common Name	Latin Name	Conservation Status
ANSERIFORMES	Red-crested Pochard	*Netta rufina*	Conservation Concern (CC)
ANSERIFORMES	Ferruginous Duck	*Aythya nyroca*	Globally Threatened (GT), Conservation Concern (CC)
ANSERIFORMES	Smew	*Mergellus albellus*	
PODICIPEDIFORMES	Little Grebe	*Tachybaptus ruficollis*	Conservation Concern (CC), Endemic Race
PODICIPEDIFORMES	Great Crested Grebe	*Podiceps cristatus*	
PHOENOCOPTERIFORMES	Greater Flamingo	*Phoenicopterus roseus*	Conservation Concern (CC)
CICONIIFORMES	Black Stork	*Ciconia nigra*	Conservation Concern (CC)
CICONIIFORMES	Western White Stork	*Ciconia ciconia*	
CICONIIFORMES	Eurasian Spoonbill	*Platalea leucorodia*	Conservation Concern (CC)
CICONIIFORMES	Eurasian Bittern	*Botaurus stellaris*	Conservation Concern (CC)
CICONIIFORMES	Black-crowned Night Heron	*Nycticorax nycticorax*	
CICONIIFORMES	Squacco Heron	*Ardeola ralloides*	
CICONIIFORMES	Western Cattle Egret	*Bubulcus ibis*	
CICONIIFORMES	Grey Heron	*Ardea cinerea*	
CICONIIFORMES	Purple Heron	*Ardea purpurea*	
CICONIIFORMES	Western Great Egret	*Ardea alba*	
CICONIIFORMES	Little Egret	*Egretta garzetta*	
PELECANIFORMES	Great White Pelican	*Pelecanus onocrotalus*	Conservation Concern
PELECANIFORMES	Pygmy Cormorant	*Phalacrocorax pygmeus*	Conservation Concern (CC)
PELECANIFORMES	Great Cormorant	*Phalacrocorax carbo*	
FALCONIFORMES	Western Osprey	*Pandion haliaetus*	
FALCONIFORMES	Black Kite	*Milvus migrans*	
FALCONIFORMES	Lammergeier	*Gypaetus barbatus*	Conservation Concern (CC)
FALCONIFORMES	Egyptian Vulture	*Neophron percnopterus*	Globally Threatened (GT), Conservation Concern (CC)
FALCONIFORMES	Eurasian Griffon Vulture	*Gyps fulvus*	
FALCONIFORMES	Short-toed Snake Eagle	*Circaetus gallicus*	
FALCONIFORMES	Western Marsh Harrier	*Circus aeruginosus*	
FALCONIFORMES	Hen Harrier	*Circus cyaneus*	
FALCONIFORMES	Pallid Harrier	*Circus macrourus*	Globally Threatened (GT), Conservation Concern (CC)
FALCONIFORMES	Levant Sparrowhawk	*Accipiter brevipes*	Conservation Concern (CC)
FALCONIFORMES	Eurasian Sparrowhawk	*Accipiter nisus*	
FALCONIFORMES	Steppe Buzzard	*Buteo buteo vulpinus*	
FALCONIFORMES	Long-legged Buzzard	*Buteo rufinus*	
FALCONIFORMES	Greater Spotted Eagle	*Aquila clanga*	Globally Threatened (GT), Conservation Concern (CC)
FALCONIFORMES	Steppe Eagle	*Aquila nipalensis*	Conservation Concern (CC)
FALCONIFORMES	Eastern Imperial Eagle	*Aquila heliaca*	Globally Threatened (GT), Conservation Concern (CC)
FALCONIFORMES	Golden Eagle	*Aquila chrysaetos*	Conservation Concern (CC)
FALCONIFORMES	Booted Eagle	*Aquila pennata*	
FALCONIFORMES	Bonelli's Eagle	*Aquila fasciatus*	
FALCONIFORMES	Lesser Kestrel	*Falco naumanni*	Globally Threatened (GT), Conservation Concern (CC)
FALCONIFORMES	Common Kestrel	*Falco tinnunculus*	
FALCONIFORMES	Merlin	*Falco columbarius*	
FALCONIFORMES	Eurasian Hobby	*Falco subbuteo*	
FALCONIFORMES	Lanner Falcon	*Falco biarmicus*	Conservation Concern (CC)

Order	Common Name	Latin Name	Conservation Status
FALCONIFORMES	Barbary Falcon	*Falco pelegrinoides*	
GRUIFORMES	Purple Swamphen	*Porphyrio porphyrio*	Conservation Concern (CC)
GRUIFORMES	Common Moorhen	*Gallinula chloropus*	
GRUIFORMES	Eurasian Coot	*Fulica atra*	
CHARADRIIFORMES	Black-winged Stilt	*Himantopus himantopus*	
CHARADRIIFORMES	Pied Avocet	*Recurvirostra avosetta*	
CHARADRIIFORMES	Northern Lapwing	*Vanellus vanellus*	
CHARADRIIFORMES	Spur-winged Lapwing	*Vanellus spinosus*	Conservation Concern (CC)
CHARADRIIFORMES	Red-wattled Lapwing	*Vanellus indicus*	
CHARADRIIFORMES	White-tailed Lapwing	*Vanellus leucurus*	Conservation Concern (CC)
CHARADRIIFORMES	Little Ringed Plover	*Charadrius dubius*	
CHARADRIIFORMES	Common Snipe	*Gallinago gallinago*	
CHARADRIIFORMES	Common Redshank	*Tringa totanus*	
CHARADRIIFORMES	Common Greenshank	*Tringa nebularia*	
CHARADRIIFORMES	Common Sandpiper	*Actitis hypoleucos*	
CHARADRIIFORMES	Little Stint	*Calidris minuta*	
CHARADRIIFORMES	Curlew Sandpiper	*Calidris ferruginea*	
CHARADRIIFORMES	Collared Pratincole	*Glareola pratincola*	Conservation Concern (CC)
CHARADRIIFORMES	Slender-billed Gull	*Chroicocephalus genei*	Conservation Concern (CC)
CHARADRIIFORMES	Common Black-headed Gull	*Chroicocephalus ridibundus*	
CHARADRIIFORMES	Great Black-headed Gull	*Larus ichthyaetus*	
CHARADRIIFORMES	Yellow-legged Gull	*Larus michahellis*	
CHARADRIIFORMES	Armenian Gull	*Larus armenicus*	Conservation Concern (CC)
CHARADRIIFORMES	Gull-billed Tern	*Gelochelidon nilotica*	
CHARADRIIFORMES	Caspian Tern	*Hydroprogne caspia*	Conservation Concern (CC)
CHARADRIIFORMES	Little Tern	*Sternula albifrons*	
CHARADRIIFORMES	Common Tern	*Sterna hirundo*	
CHARADRIIFORMES	Whiskered Tern	*Chlidonias hybrida*	
CHARADRIIFORMES	White-winged Tern	*Chlidonias leucopterus*	
CHARADRIIFORMES	Pin-tailed Sandgrouse	*Pterocles alchata*	Conservation Concern (CC)
COLUMBIFORMES	Rock Dove	*Columba livia*	
COLUMBIFORMES	Common Woodpigeon	*Columba palumbus*	
COLUMBIFORMES	European Turtle Dove	*Streptopelia turtur*	Conservation Concern (CC)
COLUMBIFORMES	Eurasian Collared Dove	*Streptopelia decaocto*	
COLUMBIFORMES	Laughing Dove	*Stigmatopelia senegalensis*	
CUCULIFORMES	Common Cuckoo	*Cuculus canorus*	
STRIGIFORMES	Little Owl	*Athene noctua*	
APODIFORMES	Alpine Swift	*Tachymarptis melba*	
APODIFORMES	Common Swift	*Apus apus*	
APODIFORMES	Little Swift	*Apus affinis*	
CORACIFORMES	European Roller	*Coracias garrulus*	Globally Threatened (GT), Conservation Concern (CC)
CORACIFORMES	White-throated Kingfisher	*Halcyon smyrnensis*	
CORACIFORMES	Common Kingfisher	*Alcedo cristata*	
CORACIFORMES	Pied Kingfisher	*Ceryle rudis*	
CORACIFORMES	Blue-cheeked Bee-eater	*Merops persicus*	
CORACIFORMES	European Bee-eater	*Merops apiaster*	
CORACIFORMES	Eurasian Hoopoe	*Upupa epops*	

Order	Common Name	Latin Name	Conservation Status
PICIFORMES	Eurasian Wryneck	*Jynx torquilla*	
PICIFORMES	Lesser Spotted Woodpecker	*Dendrocopos minor*	
PICIFORMES	Middle Spotted Woodpecker	*Dendrocopos medius*	
PICIFORMES	Syrian Woodpecker	*Dendrocopos syriacus*	
PICIFORMES	European Green Woodpecker	*Picus viridis*	
PASSERIFORMES	Red-backed Shrike	*Lanius collurio*	
PASSERIFORMES	Lesser Grey Shrike	*Lanius minor*	
PASSERIFORMES	Woodchat Shrike	*Lanius senator*	
PASSERIFORMES	Masked Shrike	*Lanius nubicus*	Conservation Concern (CC)
PASSERIFORMES	Eurasian Golden Oriole	*Oriolus oriolus*	
PASSERIFORMES	Eurasian Jay	*Garrulus glandarius*	
PASSERIFORMES	Eurasian Magpie	*Pica pica*	
PASSERIFORMES	Red-billed Chough	*Pyrrhocorax pyrrhocorax*	
PASSERIFORMES	Yellow-billed Chough	*Pyrrhocorax graculus*	
PASSERIFORMES	Western Jackdaw	*Corvus monedula*	
PASSERIFORMES	Rook	*Corvus frugilegus*	
PASSERIFORMES	Hooded Crow	*Corvus cornix*	
PASSERIFORMES	Northern Raven	*Corvus corax*	
PASSERIFORMES	Sombre Tit	*Poecile lugubris*	Conservation Concern (CC)
PASSERIFORMES	Great Tit	*Parus major*	
PASSERIFORMES	Eurasian Blue Tit	*Cyanistes caeruleus*	
PASSERIFORMES	Calandra Lark	*Melanocorypha calandra*	
PASSERIFORMES	Desert Lark	*Ammomanes deserti*	
PASSERIFORMES	Greater Short-toed Lark	*Calandrella brachydactyla*	
PASSERIFORMES	Lesser Short-toed Lark	*Calandrella rufescens*	
PASSERIFORMES	Crested Lark	*Galerida cristata*	
PASSERIFORMES	Woodlark	*Lullula arborea*	
PASSERIFORMES	Eurasian Skylark	*Alauda arvensis*	
PASSERIFORMES	Horned Lark	*Eremophila alpestris*	
PASSERIFORMES	White-eared Bulbul	*Pycnonotus leucotis*	Conservation Concern (CC)
PASSERIFORMES	Sand Martin	*Riparia riparia*	
PASSERIFORMES	Barn Swallow	*Hirundo rustica*	
PASSERIFORMES	Red-rumped Swallow	*Cecropis daurica*	
PASSERIFORMES	Eurasian Crag Martin	*Ptyonoprogne rupestris*	
PASSERIFORMES	Pale Crag-martin	*Ptyonoprogne obsoleta*	
PASSERIFORMES	Common House Martin	*Delichon urbicum*	
PASSERIFORMES	Cetti's Warbler	*Cettia cetti*	
PASSERIFORMES	Long-tailed Tit	*Aegithalos caudatus*	
PASSERIFORMES	Willow Warbler	*Phylloscopus trochilus*	
PASSERIFORMES	Common Chiffchaff	*Phylloscopus collybita*	
PASSERIFORMES	Great Reed Warbler	*Acrocephalus arundinaceus*	
PASSERIFORMES	Moustached Warbler	*Acrocephalus menanopogon*	
PASSERIFORMES	Sedge Warbler	*Acrocephalus schoenobaenus*	

Order	Common Name	Latin Name	Conservation Status
PASSERIFORMES	Eastern Olivaceous Warbler	*Iduna pallida*	
PASSERIFORMES	Upcher's Warbler	*Hippolais languida*	
PASSERIFORMES	Icterine Warbler	*Hippolais icterina*	
PASSERIFORMES	Graceful Prinia	*Prinia gracilis*	
PASSERIFORMES	Iraq Babbler	*Turdoides altirostris*	Conservation Concern (CC), Endemic
PASSERIFORMES	Eurasian Blackcap	*Sylvia atricapilla*	
PASSERIFORMES	Lesser Whitethroat	*Sylvia curruca*	
PASSERIFORMES	Eastern Orphean Warbler	*Sylvia crassirostris*	
PASSERIFORMES	Common Whitethroat	*Sylvia communis*	
PASSERIFORMES	Menetries's Warbler	*Sylvia mystacea*	
PASSERIFORMES	Winter Wren	*Troglodytes troglodytes*	
PASSERIFORMES	Eurasian Nuthatch	*Sitta europaea*	
PASSERIFORMES	Western Rock Nuthatch	*Sitta neumayer*	Conservation Concern (CC)
PASSERIFORMES	Eastern Rock Nuthatch	*Sitta tephronota*	Conservation Concern (CC)
PASSERIFORMES	Common Starling	*Sturnus vulgaris*	
PASSERIFORMES	Eurasian Blackbird	*Turdus merula*	
PASSERIFORMES	Mistle Thrush	*Turdus viscivorus*	
PASSERIFORMES	European Robin	*Erithacus rubecula*	
PASSERIFORMES	Thrush Nightingale	*Luscinia luscinia*	
PASSERIFORMES	Common Nightingale	*Luscinia megarhynchos*	
PASSERIFORMES	White-throated Robin	*Irania gutturalis*	Conservation Concern (CC)
PASSERIFORMES	Rufous-tailed Scrub Robin	*Cercotrichas galactotes*	
PASSERIFORMES	Western Black Redstart	*Phoenicurus ochruros*	
PASSERIFORMES	Common Redstart	*Phoenicurus phoenicurus*	
PASSERIFORMES	Whinchat	*Saxicola rubetra*	
PASSERIFORMES	European Stonechat	*Saxicola rubicola*	
PASSERIFORMES	Isabelline Wheatear	*Oenanthe isabellina*	
PASSERIFORMES	Northern Wheatear	*Oenanthe oenanthe*	
PASSERIFORMES	Kuridstan Wheatear	*Oenanthe xanthoprymna*	
PASSERIFORMES	Eastern Black-eared Wheatear	*Oenanthe melanoleuca*	
PASSERIFORMES	Eastern Mourning Wheatear	*Oenanthe lugens*	
PASSERIFORMES	Finsch's Wheatear	*Oenanthe finschii*	Conservation Concern (CC)
PASSERIFORMES	Rufous-tailed Rock Thrush	*Monticola saxatilis*	
PASSERIFORMES	Blue Rock Thrush	*Monticola solitarius*	
PASSERIFORMES	Spotted Flycatcher	*Muscicapa striata*	
PASSERIFORMES	Red-breasted Flycatcher	*Ficedula parva*	
PASSERIFORMES	White-throated Dipper	*Cinclus cinclus*	
PASSERIFORMES	House Sparrow	*Passer domesticus*	
PASSERIFORMES	Spanish Sparrow	*Passer hispaniolensis*	
PASSERIFORMES	Dead Sea Sparrow	*Passer moabiticus*	Conservation Concern (CC)
PASSERIFORMES	Pale Rockfinch	*Carpospiza brachydactyla*	Conservation Concern (CC)

Order	Common Name	Latin Name	Conservation Status
PASSERIFORMES	Rock Sparrow	*Petronia petronia*	
PASSERIFORMES	Yellow-throated Sparrow	*Gymnoris xanthocollis*	Conservation Concern (CC)
PASSERIFORMES	Radde's Accentor	*Prunella ocularis*	Conservation Concern (CC)
PASSERIFORMES	Western Yellow Wagtail (includes all races)	*Motacilla flava*	
PASSERIFORMES	Grey Wagtail	*Motacilla cinerea*	
PASSERIFORMES	White Wagtail	*Motacilla alba*	
PASSERIFORMES	Tree pipit	*Anthus trivialis*	
PASSERIFORMES	Red-throated Pipit	*Anthus cervinus*	
PASSERIFORMES	Water Pipit	*Anthus spinoletta*	
PASSERIFORMES	Common Chaffinch	*Fringilla coelebs*	
PASSERIFORMES	European Greenfinch	*Carduelis chloris*	
PASSERIFORMES	Eurasian Siskin	*Carduelis spinus*	
PASSERIFORMES	European Goldfinch	*Carduelis carduelis*	
PASSERIFORMES	Common Linnet	*Carduelis cannabina*	
PASSERIFORMES	Desert Finch	*Rhodospiza obsoletus*	
PASSERIFORMES	Corn Bunting	*Emberiza calandra*	
PASSERIFORMES	Yellowhammer	*Emberiza citrinella*	
PASSERIFORMES	Pine Bunting	*Emberiza leucocephalos*	
PASSERIFORMES	Rock Bunting	*Emberiza cia*	
PASSERIFORMES	Grey-necked Bunting	*Emberiza buchanani*	
PASSERIFORMES	Smyrna Bunting	*Emberiza semenowi*	Globally Threatened (GT), Conservation Concern (CC)
PASSERIFORMES	Ortolan Bunting	*Emberiza hortulana*	
PASSERIFORMES	Black-headed Bunting	*Emberiza melanocephala*	
PASSERIFORMES	Common Reed Bunting	*Emberiza schoeniclus*	

Appendix E

List of vegetation cover

Local Indigenous Tree Species

Oak trees form the main species of the mountain forests. *Quercus brantii (balut)* has the widest range, with Q. *infectoria* commonly admixed, occurring more frequentlyon the more favorable sites. Q. *libani (dindar) is* found in the northern mountains above 1,500 meters elevation. The following tree species are found commonly mixed with the oak trees: *Juniperus oxycedrus, Pistacia mutica, Pyrus syriaca, Cratoegus azarolus* and P. *monagyna, Acer monspessulanum.* Along mountain stream banks willows, *Salix purpurea* and S. *medemii,* plane, *Platanus orientalis,* popular, *Populus euphraca,* and ash, *Fraxinus rotundifolia,* occur and in so me places wild groves of walnut, *Juglans regia. Pinus brutia* occurs mixed with the oak forest in a restricted area of about 500 km^2 in the Zawita-Atrush district of Mosul Liwa, and apart from the more widely occurring juniper represents the only coniferous forest found in Iraq.

Table E.1: List local indigenous tree species

Source: Nova Woodbury, BlueFox Geomatics Inc, Canada 2005.

Common Name	**Latin Name**
Oak	*Quercus brantii (balut)* Q. *infectoria* Q. *libani (dindar)* Q. *aegilopidis* Q. *aegilopidis-infectoriae*
Juniper	*Juniperus oxycedrus*
Pistachio	*Pistacia mutica*
	Pyrus syriaca P. *monagyna*
	Cratoegus azarolus
Maple	*Acer monspessatanum*
Willow	*Salix purpurea* S. *medemH-* S. *alba* S. *acmophvlila*
Plane	*Platanus orientalis*
Poplar	*Populus euphraca*
Ash	*Fraxinus rotundifolia*
Walnut	*Juglans regia*
Pine	*Pinus brutia* (pinus halepensis var. brutia)
Tamarisk	*Tamarix,*
Plum	Prunus orientalis

The main species in the lowland forests are species of willow (Salix purpurea predominating in the northern parts and S. alba and S. acmophylila occurring in the south), Populus'euphratica, and different species of Tamarix, the trees often forming thickets with brambles and creepers of .sucb density as to be impenetrable except to the wild pigs which occupy these forests.

The northern part of Iraq is a rich center of diversity for a number of stone fruits, both

domesticated and wild. Evergreen fruit trees, including date palm predominate in the central and southern parts of the country. A country-wide program was launched by the State Board for Agricultural Research and Faculties of Agriculture to collect characterize and evaluate the genetic resources of Pomegranates, Pistachio, Grapes, Olives and Apples.

Fruit Tress Date palm, Pomegranate, Pistachio, Grape, Olive, Apple, Plum, Pear, Apricot Peach.

A table shows the characteristics of different tree and plant species that are both indigenous to the area, or will grow weil. The list should include: Deciduous Trees, Coniferous Trees, Shrubs, Wetland Species, Grasses, and Perennial Wildflowers. Kelowna, British Columbia, Canada has a similar c1imate to the Sulaimaniyah Territory. Some suggested Deciduous and Coniferous Trees for Kelowna include:

Table E.2: Characteristics of different indigenous tree and plant species of the area

Source: Nova Woodbury, BlueFox Geomatics Inc, Canada 2005.

Species	Availability L-Local R-Regional	Features	Height	Light & Soil Tolerances	Comments
Deciduous Tree					
Acer glabrum var.Douglasii Douglas maple*	L	showy autumn colour; small, greenish- yelJow flowers	to 10m	sun/part-sun, moderately moist	plant on upper bank; provides food source in form of wingshaped seeds
Betula occidentalis Water birch*	L	coarse shrub or smalldeciduous tree; fruit	to 10m	sun, moderately moist to wet-mod. moist	plant on lower bank; habitat for many species ofbirds and mammals
Betula papyri/era Paper birch	L	often multi-stemmed with characteristic white peeling bark	to 40m	sun, moderately moist	seeds provide food for birds
Crataegus douglasii Black hawthom*	L	numerous sharp, 3 cm long thoms, white flowers, purplish-black fruit	to 8m	sun, moderately moist	provides food for birds through the winter; hawthomthickets are good denning and nestirrg-sites for SmalJ birds and mammals
Populus tremuloides Trembling aspen*	L	fast growing; silvergrey bark, trembling leaves, yellow autumn colour; hardy	to 20m	sun, moderately moist to dry-moderately moist	rotted sterns rovide habitat for cavity-nesting birds; elk and deer browse on young aspen; important food source for animals, including birds
Populus balsamifera ssp. *trichocarpa* Black cottonwood	L	fast growing; fragrant leaves; hardy; shadeintolerant	to 40m	sun to part- sun, moderately moist to wet-moderately moist	important tabilizer of streambanks, nhances fish habitat; decaying leaves provide food source for larvae ofcaddis flies, mayflies and other insects-the food for kokanee
Prunus	L	leaves lance-	Usually	sun,	scattered; often

pensylvanica Pin cherry		shaped with a tapering sharp point, flowers and fruit 5-7 in a loose cluster	I-Sm, but up to 12m	moderatelymoist to wet-moderately moist	abundant after fire; berries favoured by many birds
Prunus virginiana Western chokecherry	L	white flowers, edible red, urple or black frojt,	to 10m	sun,moderately moist to dry-mod. moist	berries attract birds and mammals; butterfly larval food plant; deer browse.
Coniferous Tree					
Larix occidentalis Western larch (Tamarack)	L	four-sided needles, turn bright yellow in auturnn	to 55m	very shade-tolerant, dry-moderately moist	thick fire-resistant bark; bark & foliage used medicinally, natural sugar in gum can be tapped to make syrup mixed with sweeteners
Picea engelmani Engelmann spruce	L	dense prickly needles, branches swoop to ground	to 35m	part sun, moderately moist	seeds eaten by birds and squirrels; provides cover for wildlife
Pinus contorta var. *latifolia* Interior lodgepole pi ne	L	needles in bunches of 2	20-25m	sun, various soil types	forms straight broad trunk with little taper; cones require fire to release seeds
Pinus monticola Western white pine	R	needles occur in bundles of 5	30-50m	part-sun, somewhat shade-tolerant; wide range of soi!s	forms straight broad trunk with little taper, open conical crown with whorled branches and ascending tips
Pinus ponderosa Ponderosa pine	L	needles occur in bundles of 3; long taproot - transplant only small specimens	15-30m	sun, dry-moderately moist	seeds attract many birds and sm all mammals; also provide winter range for many wildlife species (ex: deer and elk)
Pseudotsuga menziesii var. *glauca* Interior douglas fir	L	rapid growing evergreen	to 40m	sun, dry-moderately moist	birds, squirrels, chipmunks, and mice eat the seeds; bears scrape off bark and eat the cambium layer beneath; deer browse on young trees
Thuja plicata Western red cedar	L	rapid growing evergreen, drooping foliage	to 60m	sun to part-sun, moderately moist	provides food in form of seed cones; seeds eaten by birds; deer browse on cedar in winter.

Appendix F

Maps of the CSC

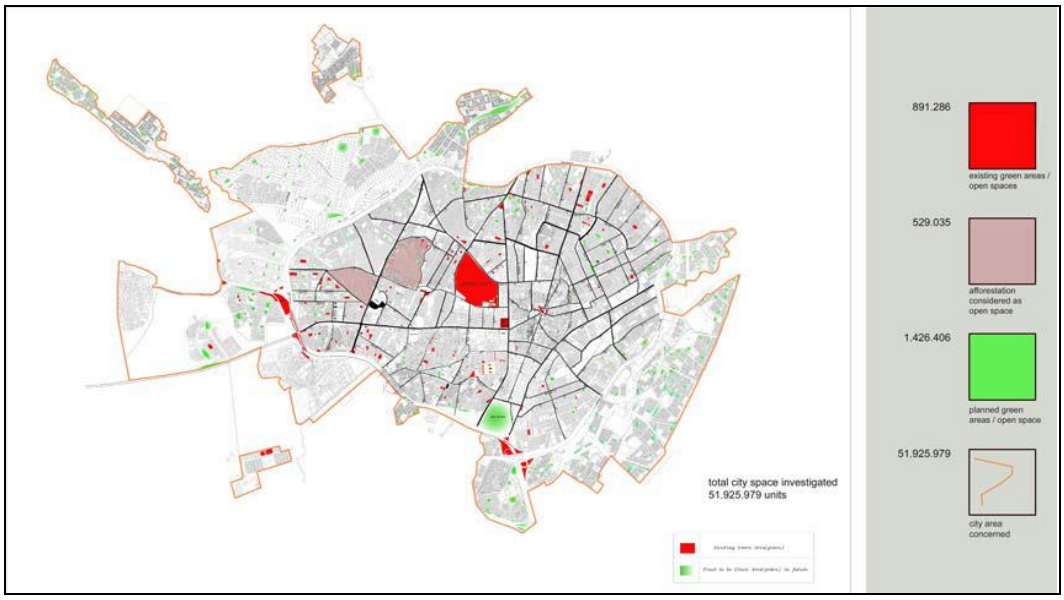


Figure F.1: Study Area for calculating total green space ratio in CSC

Source: Municipality of Sulaymani City, IGCO 2009.

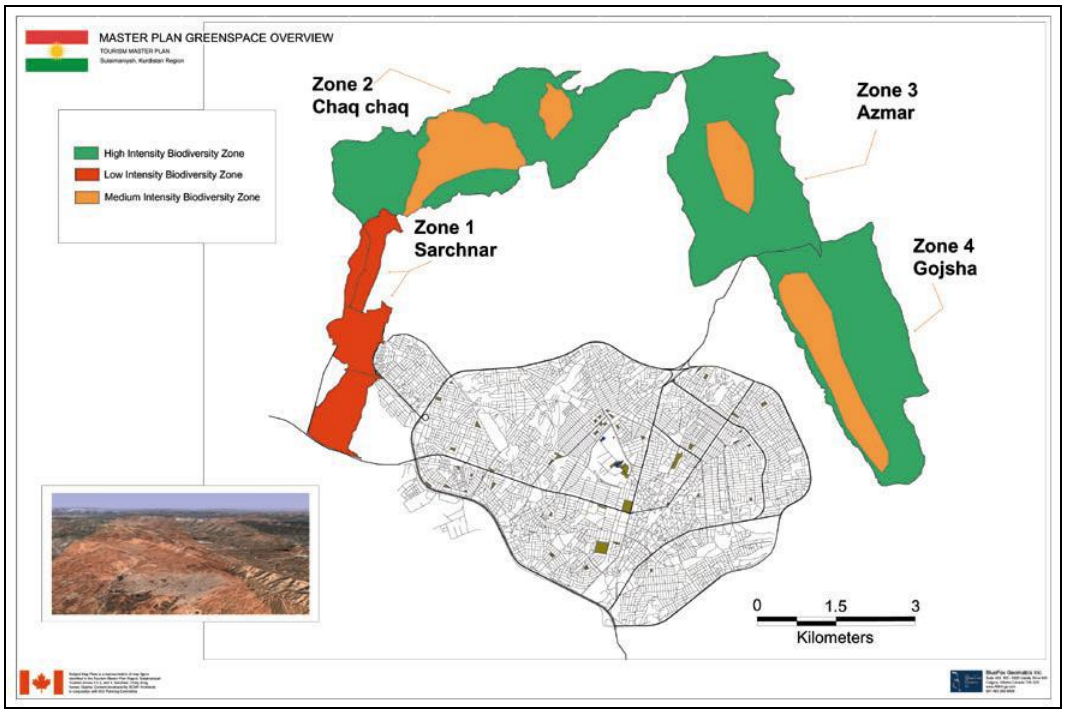


Figure F.2: Sulaimany Tourism Masterplan

Source: Ministry of Council, BlueFox Geomatics Inc, Canada (2005).

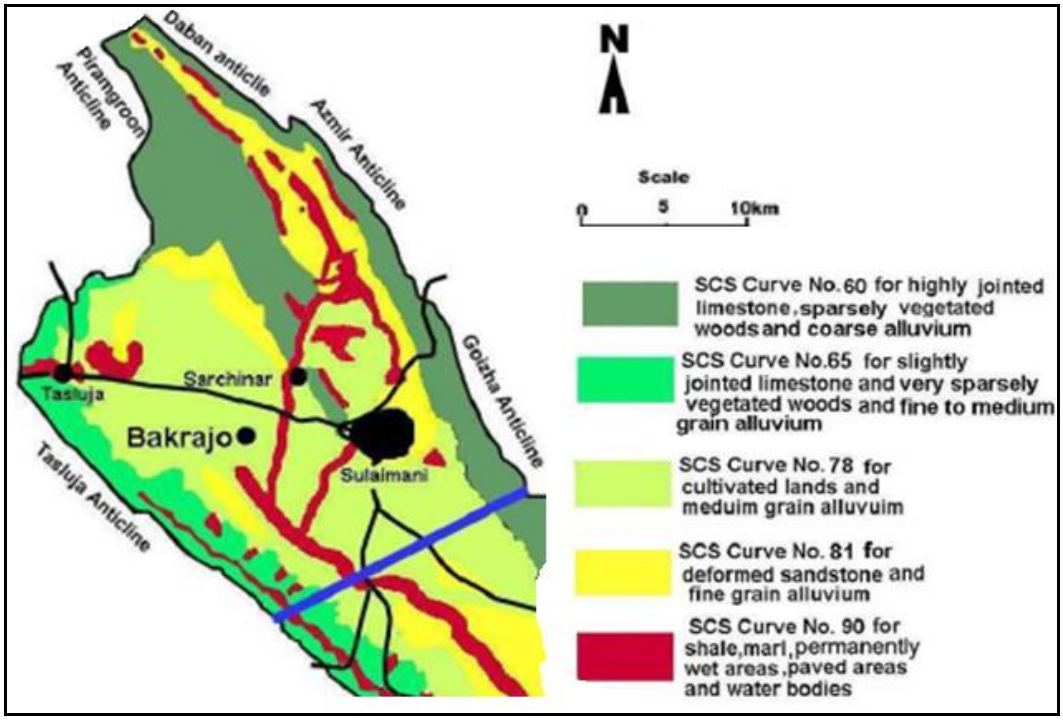


Figure F.3: Differentiation of the basin surface area into different runoff zones according to runoff coefficient and curve numbers

Source: http://www.kurdistan-geology.com/

Appendix G:

Climatic Characteristic in the CSC

Relative Humidity

Relative Humidity shows a variation between maximum (67.9%) in January and minimum (28.4%) in June. Relation between relative humidity and air temperature (Figure G.1) is often so pronounced that the relative humidity pattern is almost the exact inverse of the air temperature pattern[255].

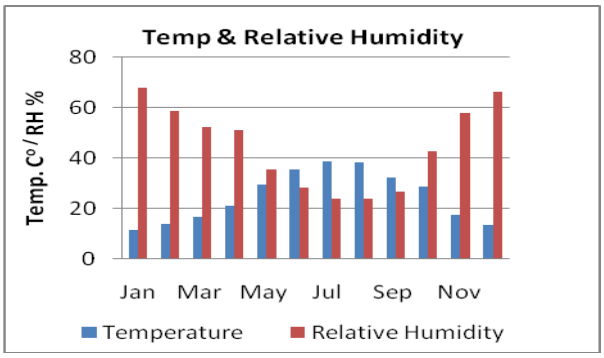
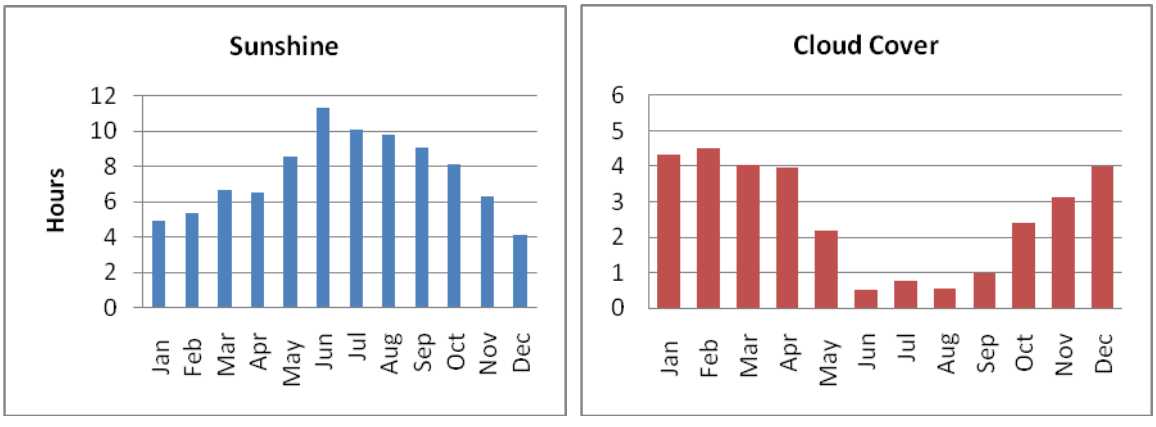


Figure G.1: Diverse relation of mean monthly relative humidity and mean monthly temperature (2000-2009) in CSC

Source: Author, 2010.

Sunshine and Cloud Cover

The sunshine duration may vary between 50 % in the winter months and 90 % during the summer. Sunshine shows the length of day hours. Figure G.2-L shows the monthly sunshine duration average which ranges between (11.3 hours) in June and short duration (4.1 hour) in December. The mean annual duration of sunshine reaches (7.6 hours). Also the cloud cover is shown in Figure G.2 -R for the same time interval. These two parameters affect the photosynthetic activity and also affects the city's climate in term of air pollution.



[255] Griffiths JF. 1976. Climate and the environment: the atmospheric impact on man.

Figure G.2: Mean monthly sunshine (L) and cloud cover (R) (2000-2009) in CSC

Source: Author, 2010.

Evaporation

Evaporation increases with increasing air temperature, pressure, solar energy and wind speed, while they are inversely related to relative humidity (Figure). Maximum reachable point of evaporation in the area is in Summer (July) which equals to (156 mm) and minimum recorded limit is (20.7 mm) in Winter (January) Mean annual evaporation for the recorded period is equal to (71 mm).

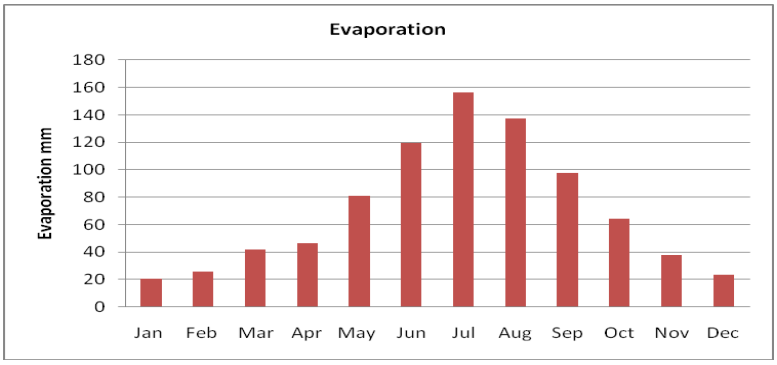


Figure G.3: Mean monthly evaporation (2000-2009) in CSC

Source: Author, 2010.

In a research by Jamil Jala forecasted rainfall in Sulaimaniyah City for next decade by using Mini-tab program, and Holt-winter method. A ten year forecast results of precipitation in Sulaimaniyah (N 35° 33' 24", E 45° 27' 11", 850 m) region were predicted up to 2018, with the range of (300-1059 mm) and an average rainfall of 658 mm. This is indication of presence of no drought in the coming 10 years, see Figure G.4.

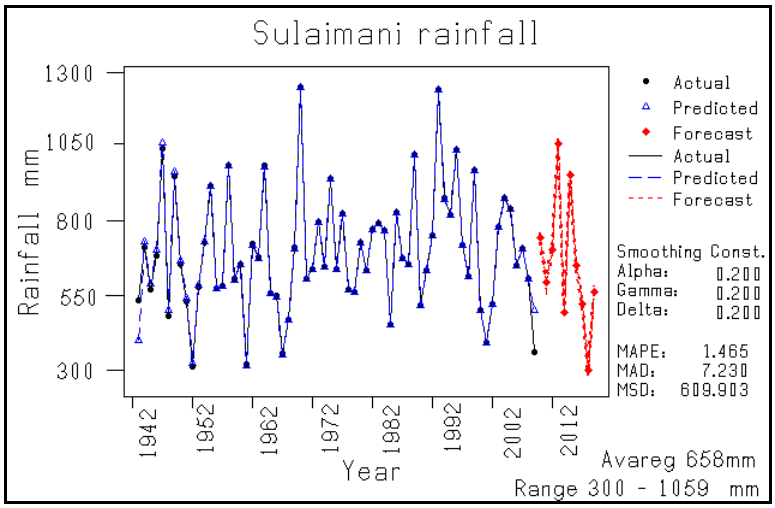


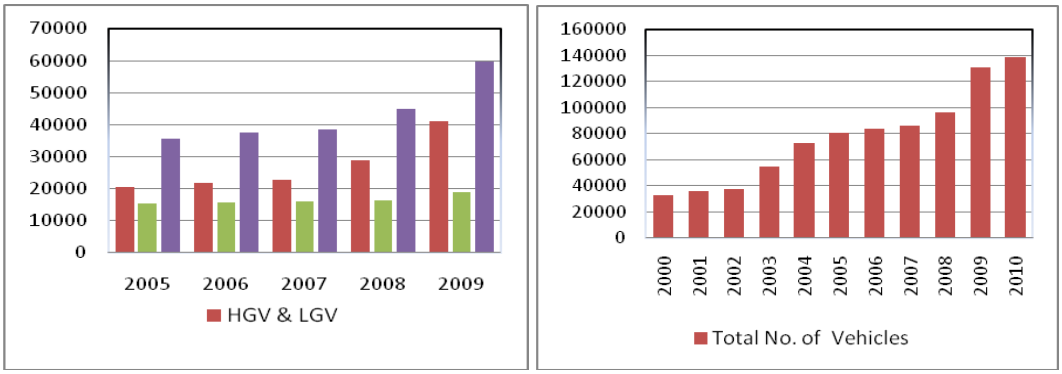
Figure G.4: A ten year forecast results of rainfall at Sulaimaniyah meteorological station from 1942-2008

Source: Jamil Jalal, 2008.

Appendix H:

Automotive Traffic Data

Figure H.1, illustrate the incremental trend of number of vehicles at a City and Governorate level. It is worth to be highlighted that the statistics for 2010, only representing the number of vehicle recorded up to May 2010.



*Ministry of Interior, General directorate of Traffic in Sulaimaniyah, Statistics Department, 2010. Unpublished data.

Figure H.1: Trend of recorded vehicles in CSC (2005-2009) (L), trend of recorded vehicles in Sulaimaniyah governorate (2000-2009) (R)

Source: Author, 2010.

To give a general understanding about the traffic volume in the CSC, see Figure F.5 that illustrate the traffic load diagram shows the traffic load profile of a normal weekday determined on the basis of the count data collected in 2006 and its projection.

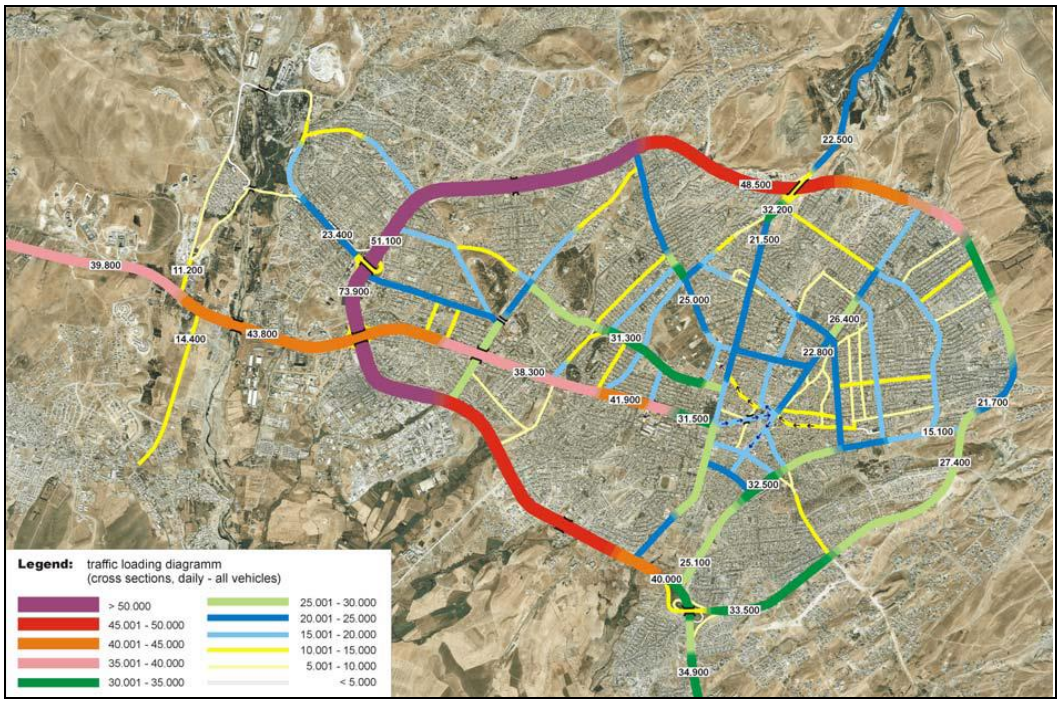


Figure H.2: Diagram of traffic loads in CSC (main roads, daily load profile)
Source: Municipality of Sulaymani City, IGCO 2009.

Appendix I:
Land Cover Map

The land Cover map is a basic layer for evaluating the effect of vegetation cover (green percentage) in improving the climatic engineering parameters in urban areas. Due to availability of data this layer couldn't be created by automatic classification method. The land cover at the city scale has been adopted precisely but the private green space (impervious surface) at plot scale has not been included, which have a direct effect on the selected ecosystem services at a city level. That is why on the base of conventional planning method by taking certain sample (of the urban morphology categories that is dominated by residential use) for manual digitization and under the light of Municipalities calcification, certain assumption have been made. The spatial pattern of sample distribution was correlated with the pattern of urban expansion in the CSC.
Based on historical urban development of the CSC that shapes strongly the urban pattern three main parts have been selected and digitized for this purpose.
In the city center (section 6) which consists of 8 neighborhood one neighborhood is taken for digitizing all pervious surfaces. The total area under study is 206176 m^2 only (643 m^2) 0.31% is public green and (4468.5 m^2) 2.17 % is private green space, see Figure I.1. Accordingly the average private green space for City Center is estimated as 2%.

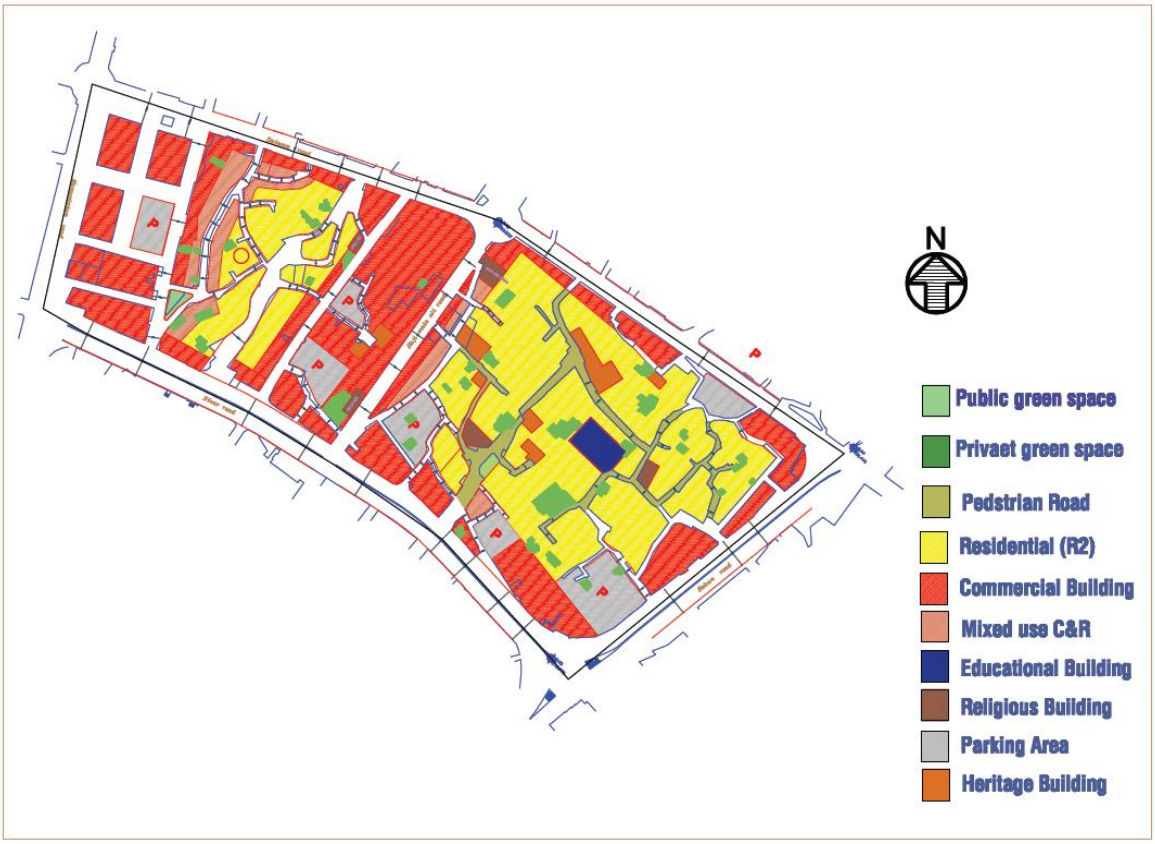


Figure I.1: Land use of Sarshaqm neighborhood in City Center

Source: Author, 2010, based on City center department data, Municipality of Sulaymani City.

Another neighborhood within the development stage of 1970s, together with an educational complex has taken for investigation, see figure G.2. The finding for residential part was green area was 23% , built-up 45.3% and open area 31.7%, in total 23% pervious surface and 77% impervious, this regardless of surrounding roads. While for educational complex finding was 8.6%, 35.8% and 55.6% green area, built-up and open area correspondingly, in total 8.6 % pervious surface and 91.4 % impervious surface.

A part of neighborhood within the development stage of 1980s, has taken for investigation, see figure 3. The finding was 16.8%, 68% and 15.2% green area, built-up and open area correspondingly, in total 16.8 % pervious surface and 83.2 % impervious surface.

Figure I.2: Land cover map gor residential block with an educational complex
Source: Author, 2010.

While the sample from development stage of 1990s and on, gave the poorest percentage in term of vegetation cover. The finding was 3% green area, 70% to 85 % built-up and 27%, to 12 % open area correspondingly, in total 3 % pervious surface and 97 % impervious surface.
Development of this era is mainly consisting of 'Self Produced Housing (Owner Built House)' typology the plot size has been generally allocated plots of 200 sq m by Government. The result is a fairly monotonous townscape of terraced housing, with very narrow-frontage houses and very little space, with only 2m setback without any soft pavements. The special arrangement is repetitive for the most plots with slight difference in the area. This produce a very dense and compact structure with very poor vegetation percentage, see figure G.3.

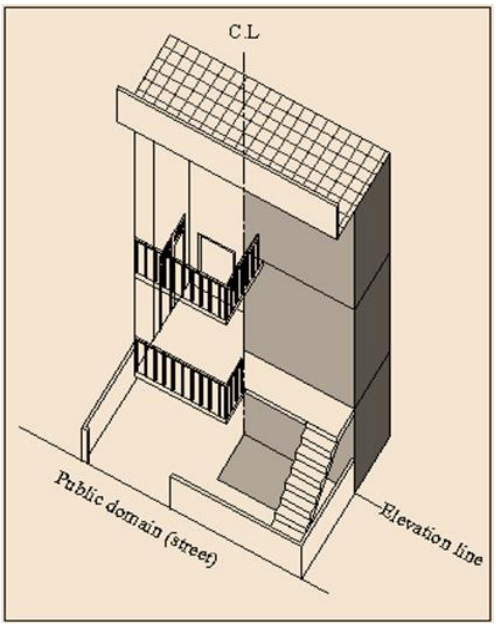


Figure I.3: Perspective of contemporary housing typology showing the percentage of open space and setback line

Source: Bnyad Abd-Qadr, 2009.

Accordingly the city land cover developed by assuming three main category of neighborhood in terms of private green percentage, and the City center as another category. It is worth to mention that this categorization took the assumption that new developed area will be filled with the same pattern and it is not free from error since it depended of digitization of a selected portion of the city. See figureG.4 illustrate the percentage of private green (pervious surface).

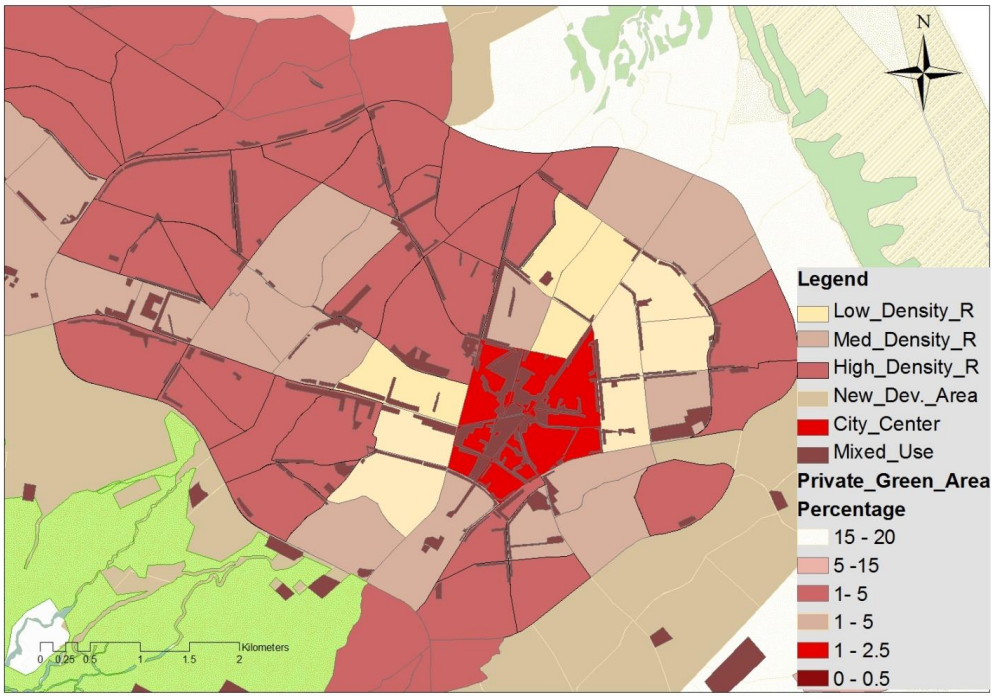


Figure I.4: Proportion of private green area at lot level within build up area in CSC

Source: Author, 2010.

After adding the proportion of public green space at a neighborhood scale, the general land cover map proposed to be used in the course of this paper for carrying out investigation.

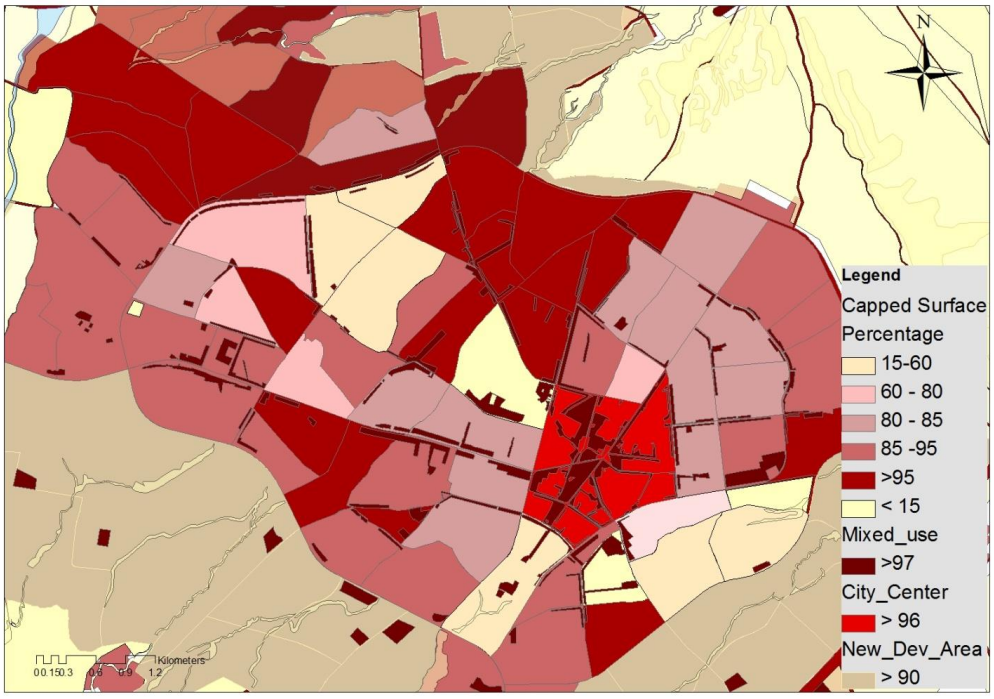


Figure I.5: Proportion of built surfaces in CSC

Source: Author, 2010.

Appendix J:

Digital Data