CLASSIFICATION IDENTIFICATION OF LAND USE/LAND COVER IN PAKISTAN FOR POLICY MAKING
A GIS AND REMOTE SENSING PERSPECTIVE: A STUDY OF PUNJAB

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Rashid Shafiq
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Submitted in partial fulfilment of the requirements for the
MS degree with specialization in Technology Management
at the faculty of management sciences,
International Islamic University,
Islamabad

Prof. M. Farooq Hussain

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بسم الله الرحمن الرحيم

DEDICATION

This research is dedicated to Almighty Allah and my loving, caring and industrious parents whose effort and sacrifice has made my dream of having this degree a reality. Words cannot adequately express my deep gratitude to them. I pray for my lovely parents live long to reap the fruits of your efforts.

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Accepted by the Faculty of
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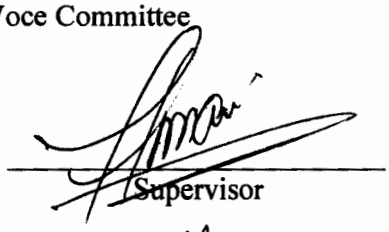
INTERNATIONAL ISLAMIC UNIVERSITY, ISLAMABAD, in partial fulfilment of the requirements for the MS Degree in Management Sciences with specialization in Technology Management.

Viva Voce Committee



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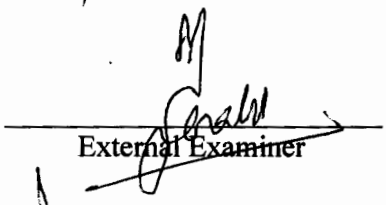

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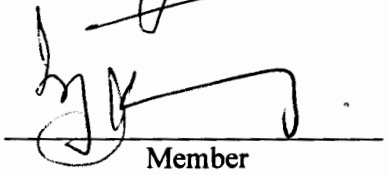

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(Rashid Shafiq)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Efficient planning and management of any land requires current and accurate information about land use/land cover. Typically, such information is provided by aerial photography and satellite imagery. Remote sensing (RS) and Geographical information system (GIS) are used to map the land use/land cover classification in three major and critical areas (Agriculture, Water bodies and Forest) in Punjab province of Pakistan. For this purpose topographic sheets are used as the base maps and different layers of satellite images for analysis of the information. For suitable sustainable developments, land use /land cover classification identification is very important to make a remarkable policy plan. Many developed and developing countries like US, UK, France, Germany and China are making their development policies based on land use/land cover classification system using RS and GIS. This study demonstrated how to classify land use/land cover of Punjab province of Pakistan, utilizing highly sophisticated and efficient Remote sensing and GIS technology.

This study has provided a case for utilizing optimum potential of land, by using RS and GIS technology. It has shown that this technology is quite effective in mapping land use/ land cover and has several advantages over the conventional ground survey methods that are time consuming, labour and resource intensive and are also conducted infrequently. This research identified different types of land use/land cover focusing on agriculture, forest and water bodies in the Punjab province, which could be of substantial use to planners and decision makers at the provincial or district level, who can compare this land use / land cover to land capability and potential and make efforts to optimize the land use/land cover.

This study has potential of replica ability for all over the Pakistan by using GIS to assimilate spatial data and generate meaningful graphical and statistical view to the planners and policy makers for minimizing the risks from unplanned and improper use of Agriculture, Water reservoirs and Forest resources.

Keywords: Remote Sensing (RS), Geographical information system (GIS), Land use/Land cover, Punjab, Pakistan.

CHAPTER ONE

1.1 INTRODUCTION

Pakistan lies between 24° and 37° North latitude and 62° and 75° East longitude covering an area of 864685.93 km^2. Nature has blessed Pakistan with rich and unique landscape, plateau plains, high mountains, deserts, Water bodies, snow cover, glaciers, rich agriculture land and forest etc.

Improper developments have shoddily altered the earth surface. Due to such developments land has a profound effect upon the socio economic factors thus resulting into an observable pattern in the land use/land cover. The public sector institutions arrangements in Pakistan lack in capabilities to identify comprehensive land use/land cover for appropriate planning and management. This lack of land use/land cover classification identification leads to failure in policy making and implementation. Therefore, it is needed to develop capabilities for identification planning and management of land use/land cover.

Land use/land cover identification has become a major component in current strategies for policy making, managing natural resources and monitoring environmental changes. Inappropriate land use leads to inefficient exploitation of natural resources, and their destruction leading to poverty and other social and economical problems (Rossiter, 1996). There is a need of classification system to meet the needs of Public sector institutions/agencies for an up-to-date overview of land use and land cover.

Land use/land cover studies can be organized into three stages:

- Detection and Classification of Land use/Land cover
- Monitoring Land use/Land cover changes
- Analysis and prediction of Land use/Land cover

First and second stage can be carried out by studying satellite images / Remote Sensing while Geographical Information System (GIS) technology is used in the third stage i-e Analysis and Prediction stage.

Remote sensing through satellite is playing very important role in mapping the earth's feature and infrastructure, disaster monitoring and management, land administration for sustainable developments, environmental impact analysis of human activities, sustainable agricultural development, monitoring the urban developments, emergency planning, monitoring of gas pipelines, coastline mapping and identification of shoreline changes, monitoring sea level rise, landslide hazard assessment, changes in soil salinity, soil erosion, soil degradation, Forest fire susceptibility, air pollution impacts, monitoring of security related issues and earthquake damage assessment.

Skyttner (2002) consider the satellite data extremely useful for the study of rapid environmental changes for example in the context of biodiversity. Likewise a combination of Remote sensing and Geographical Information System (GIS) provide a range of data on environmental properties (Foody, 2008). Snow et al (2009) allude that GIS is a powerful tool that integrates multifaceted data and transforms it into a graphical way that can be easily comprehended. Further he advocates that it also has the ability to analyse the risks and identification of the impacts. Tsai et al. (2008)

point out that GIS and decision support system collectively have become important tools for policy making worldwide.

A Geographic Information System (GIS) integrates multiple attributes of technology like software, hardware and data for capturing, analyzing, managing and displaying all forms of geographically referenced information. GIS allows viewing, understanding, interpreting, and visualizing data in many ways that expose relationships, patterns, and trends. G IS technology plays a vital role to answer questions and solve problems by looking at data in a way that is quickly understood.

GIS technology plays a very important role in decision making in the context of sites selections, responding to emergencies, identification of land classification, planning and decision making, etc. However, GIS technology is very expensive. Ramli et al, (2005) argue that due to high cost of the sophisticated commercial software, the use of GIS is limited, especially in developing countries.

In terms of land use Cowell (1998) expresses that

> *"Western nations have learned hard lessons in consequence of not considering ecological process and structures when undertaking the land use planning and development".*

For developing countries like Pakistan, which are heavily dependent on land resources for food production it is extremely important to pay serious attention to land resources and their judicious use. Therefore, the focus of this study is on the use of GIS technology in identifying land use/land cover classes in the province of Punjab.

This rich area for agriculture is facing the problems of depleting land fertility due to inefficient use of soil and water resources. The study demonstrate how to classify land use utilizing highly sophisticated and efficient Remote sensing and GIS technology Once classified the land use can then be compared to land capability to see whether this use is according to land potential, providing the basis for the planning and management of land use in the province.

1.2 OBJECTIVE

Over the past 60 years, Pakistan, specifically Punjab province is facing depletion and degradation of fertile agriculture land, Forest and water bodies, causing the conversion of Agriculture and Forest land into human settlements. These improper massive developments have led to many socio economic issues. Punjab, province of Pakistan has observed huge unplanned growth and development activities such as unplanned human settlements, improper road construction, deforestation, less/improper management of water reservoirs and many other anthropogenic activities. Unplanned developments cause loss of economy, inefficient utilization of resource and many other valuable factors. This research defines a platform for policy making in public sector of Pakistan particularly for Punjab province.

The main reason to use of RS and GIS, This technology has versatile features that can address sophisticated solution of the problems like, Resource management, land administration for sustainable developments, sustainable agriculture development, deforestation monitoring, Environmental impact assessment, Resource management, Disaster monitoring and management, and monitoring the urban developments etc. GIS system using RS data provide concise, to the point, in short time and even real time information which is directly useable by policy makers and decision makers. So, in this study we have used RS/GIS technology for accurate, efficient and in short time land use/land cover classification.

CHAPTER TWO

2.1 LITERATURE REVIEW

Land use/land cover classification plays a very important role in physical planning and development of an area or a country. Anderson (1976) describes the importance of land classification. He points out that land use/land cover data is needed by public sector institutions for better development and management of its resources and human activities such as water resources, flood control, waste water, soil erosion, agriculture, forestry etc. In USA, a steering committee has been formulated on land use information and classification. Major stakeholders of this committee are from the U.S Geological Survey, Department of the Interior, Soil Conservation Service of the U.S. Department of Agriculture, National Aeronautics and Space Administration (NASA), International Geographical Union and the Association of American Geographers. The committee is supported by Department of the Interior and National Aeronautics and Space Administration (NASA) and coordinated by the U.S. Geological Survey (U.S.G.S.). The objective of the Committee is to develop a national classification system of land use that would be receptive to inputs of data from both conventional sources and remote sensors on high-altitude aircraft and satellite platforms.

According to Zubair et al, (2006) land use and land cover affect each other. Land use/land cover is altered by anthropogenic activities as well as non-anthropogenic sources such as weather, flooding, fire, climate fluctuations and

ecosystem dynamics. Land use/land cover classifications once compared with each other help in understanding the dynamics of land use change and correcting the land use for the benefit of mankind.

Land use/land cover classification is difficult in inaccessible and physically difficult areas. Cowell (1998) argues that rapid evolution of Geographical Information System (GIS)/ Remote Sensing (RS) technology is versatile for this purpose and has permitted to collect low cost and high quality data even in these areas. Usually land use/land cover information for mountainous, rugged or areas with difficult terrain is weak and/or unreliable because of physical difficulty of approach. However, with the advancement of remote sensing, it has become relatively easy to obtain data even for such areas. In support of this argument Gitas (2001) state that collection of relevant information using traditional techniques involved major expenses to conduct large scale field surveys. These have been cut drastically with the advancement of remote sensing technology. Additionally, Feoli et al, (2003) point out that integrated use of remote sensing and geographical information system allows easy processing of large scale data and bundle of different maps. Hence, with the advancement in remote sensing and GIS technologies, these are replacing conventional methods particularly, because investigation of large scale area through conventional methods is very expensive and time consuming. Moreover comparison of variable as in the context of desertification in a specific and limited area is also easy through the use of remote sensing and GIS technology, which allow collecting data on the required parameter rapidly in the study area. (Dragan et al., 2005).

Further, it is observed that with the advancement of RS and GIS technologies faster operations are being executed as well as more accuracy is being achieved by

using these sophisticated technologies. It has been observed that image analysis expert system using GIS, provides accurate and higher quality information as compared to information obtained through the conventional methods and approaches (Huang et al, 1997).

Earth observational satellites are playing very important role in disaster management, planning, analysis and early warning system. To accomplish these tasks not only various types of spatial data is required but quick and real time data processing is also required. Remote sensing and GIS techniques providing tools for the same are being used extensively for the purpose (Louhisuo et al., 2007).

Generally two types of remote sensing techniques are used to collect information, Satellite data and airborne data. Both types of techniques have some advantages and disadvantages. Main advantage of satellite data is that it covers wide area and makes possible timely availability of temporal data but the major drawback of this technique is low resolution and small scale comparatively. Images acquired by the aircrafts, on the other hand, have high resolution providing detailed information, but airborne technique cover only small areas at a time as compared to satellite images. Moreover, Cost of the airborne data is very high compared to satellite data as well as frequent data/temporal extraction is very difficult and expensive. Moreover, Jeber et al, (2008) state that airborne systems are comparable to satellite system in some extent; however, airborne systems main shortcoming is that it poses difficulties in acquiring temporal images and the view of the earth is very limited. He also point out that airborne technique is necessarily adopted where the area of interest is very small and very accurate information is required, like landslides areas are very small in the scale in the context of satellite images so, this is the major issue in land slide

study. Therefore still the remote sensing images used for landslides assessment and monitoring are acquired by airborne technique.

To quantify the type, location and amount of land use changes multi temporal and multi spectral data is acquired by Remote sensing technology and GIS is the excellent tool that provides the features for displaying/presenting, storing and analyzing the digital data for the purpose of change detection (Wu et al., 2006).

In fact, presently, every remotely sensed material is complementarily linked with GIS. In other words we can say that GIS is mandatory for the analysis of remotely sensed data. In support of this argument Hill et al, (2003) state that today the reality is that every remote sensing image/data will exist at some stage in its lifetime in geographical information system. Ancillary, GIS and Remote sensing are versatile state of the art technologies in the world to overcome and accomplish the complicated and time consuming tasks appropriately, efficiently and effectively and in a timely manner.

Remote sensing techniques provide two type of data format for GIS assistance, Vector data and Raster data. In raster data system, the geographical data is represented and stored in the form of pixels_that is very expensive in the context of data storage space. To overcome this issue different spatial formats are being used for storage of geographic data to obtain vector images, raster images, tabular data, and regular grids or database structure. The details on Raster and Vector formats have been explained by Manso (2004). According to him, raster data is generally represented in PNG (Portable network graphic format), BMP (Bitmap), RAS (Raster), JPEG (Joint photographic expert group), Tiff (Tagged image file format), IFF

(Interchange file format) and GIF (Graphic interchange format) etc. He also describes the formats that are used to store orthogonal images, digital aerial photographs and scanned cartography are MrSID (Multiresolution seamless image database), GeoTIFF (Geographic Tagged Image File), GeoJP2 (GeoJpeg2000), ECW(Enhanced Compressed Wavelet), NITF (National Imagery Transmission Format), DEM (Digital Elevation Model), DTE, DTO (Data transfer object), GRD (Gridded data file), ADF (Arc data files), IMG (Image file), PIX (Pixel file), ERS (European remote sensing file) and INGR (Intergraph raster file) etc. Explaining about vector data, he observes that it is the most common style for data handling in geographical information system. Vector data consists of points, lines and polygons and this is the most common and natural representation of data. It is represented in DGM (Digital Geospatial Metadata), CSF (CSF File Extension), VEC (Vector data), SHP (Shape file), DWG (Drawing file), BIN (Binary Terrain file) etc.

GIS technology is being used in every field of scientific knowledge for efficient and accurate development like resource management, scientific investigations, Security, urban planning, environmental impact assessment, cartography, criminology, geographic history, marketing, logistics, and many other purposes. This sophisticated technology is being used by many countries. However, in land use planning and management GIS technology as tool has not been extensively practiced so far (Seker et al, 2004)

Holden (2000) describes that GIS is the analytical tool that allows us to implement directly the ecological view of reality and to achieve a holistic information management capability. Forcht (2000) further explains that GIS simultaneously plays different roles in different areas, GIS at the same time is a microscope, the telescope

the computer, and the xerox machine of regional analysis and synthesis of spatial data. Furthermore Hausamann et al, (2005) explains that due to Remote sensing technology it is now possible to design monitoring system of natural gas pipelines.

Geographical information system has a great potential to produce huge interactive spatial database to discuss environmental issues. Patra and Pradhan (2006) explain that for the purpose of environmental modelling GIS has the ability to produce a powerful geo-database. He also point out the importance of GIS technology and states that the organizations not following the said technology will face many problems in future. One of the outstanding features of GIS technology is that it can be linked with existing datasets. Well developed geographical information system can be integrated with legacy system to provide comprehensive data management, organization and query facilities from within a single geographical software application (Savic et al., 1997). He asserts that the most important geographic research area today is the integration of geographic data into engineering maintenance.

Haas et al., (2005) also express the importance of remote sensing and geographical information system. He used both the tools in his project titled "From the Air: the photographic record of the year". He used the 88000 physical aerial photographs in the shape of tiles; a very important and critical sector of his study was to scan these huge amounts of images and their processing in appropriate software to obtain the desirable results. Main theme of his research was to develop a geo-database for land conservation.

Various departments including public and private sector organizations are spending huge amount of money for acquiring and classifying RS data to develop land use/land cover database. Hess describes that effective landscape management can be performed from such type of database (Hess, 1994).

Anderson highlighting land use/land cover planning and analysis stated:

> *"A modern nation, as a modern business, must have adequate information on many complex interrelated aspects of its activities to make decisions. Land use is only one such aspect, but knowledge about land use and land cover has become increasingly important as the Nation plans to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, destruction of important wetlands, and loss of fish and wildlife habitat (Anderson, Hardy, Roach, & Witmer, 1976)."*

Advancement in technology, particularly procurement of high resolution imageries have enabled overcome the spatial and temporal constraints in monitoring critical sectors like water, forest, agriculture etc, earlier it was not possible to get high resolution images from satellites (0.5m-1m) and the dependence was on the aerial photography that is very costly and time consuming. Hence, Sawaya et al, (2003) point out that earlier the data was acquired by aerial photography now it is possible to get the same data from high resolution satellite imagery which has enabled the managers, planners and policy makers to create reliable data base and timely analysis of land use land cover at a national as well as local scale.

Geographical information system can be effectively used for both agriculture and forest management. It can also be utilized for monitoring water and air pollution which shows the multipurpose capability of GIS. In monitoring water pollution several attributes such as sediment load, suspended solid and salinity can also be measured with a well defined mechanism.

Skyttner (2002) strongly encourages the use of GIS and Remote sensing techniques for agriculture, soil erosion, deforestation, land transformation, population mapping, oceanography and hydrology etc while Tsai et al. (2008) point out that,

> *"Functions and application fields of GIS comprise classification, calculation, measurement, overlay analysis, network analysis, and view-shed analysis, and due to the versatility, GIS has become one of the most useful tools for decision support".*

Agriculture is very hot topic in many countries, particularly, where socio economic development depends on agriculture. Discussion on agriculture may involve resources such as soil, water, biodiversity or it may involve crop production, crop diseases etc. In the former case one may note that better soil leads to better agriculture. So, the main thing is the Soil classification that can be easily done using remote sensing and GIS. Consequently, soil information management system comprising of GIS/RS provide essential data sets for land use planning, interpretation and management (Roy et al., 2004).However, even crop production can be forecasted on the basis of crop conditions which can be used for forecasting yields and hence production. GIS based databases are being widely used in agriculture land use planning.

In the study of global change land use / land cover play a major role. Improper land use/land cover changes have largely resulted in agriculture land loss due to conversion of agriculture area into human settlements, global warming and biodiversity loss. Keeping aforesaid information it is imperative to say that land use / land cover modification can provide valuable information for decision making of environmental planning and management (Reis, 2008).

For promoting sustainability of agriculture satellite data and aerial technology of image capturing are gaining very high significance in terms of planning, management and forecasting. Agricultural potential can only be analysed when statistical data about crop pattern is available helps in keeping farmers informed on their crops conditions and related variables for example risks to their crop from diseases, locusts and the likely amount of production. Bhan et al., (n.d) stated that in India remote sensing and geographical information system is being extensively for planning and management of agriculture. It is helping in agro ecological zonation; cropping system analysis; soil erosion inventory; assessment of soil carbon dynamics; integrated mission for sustainable development and integrated agricultural drought assessment and management.

An important study on agriculture sector in Europe was conducted on rapid estimation of agriculture in Europe using remote sensing technology. The project entitled "Monitoring agriculture by remote sensing" was started with the collaboration of institute of remote sensing applications and had four major activities, crop inventories, crop yield forecasting, vegetation and crop state monitoring and the quick and timely estimation of total production of the crops of the European community's (Zenie et al, 1996).

Conversion of agricultural land into human settlement/urban land is a critical issue all over the world particularly developing countries. Cities are spreading rapidly therefore, encroachment of cities is a major problem to agricultural land and a serious threat to food security. So, to overcome this issue a strict and quick monitoring system is necessary. Conventional methods like ground surveys are time consuming and very slow so, modern techniques are required to accomplish this task in a very short time slot. To date, inevitably RS and GIS technology is being adopted for such type of activities where time and accuracy matters. Li et al, (2004) concluded that in south China urban expansion and land use patterns' spatial restructuring analysis was conducted successfully using RS and geographical information system, in this study temporal data was used of two different time slots 1988-1993 and 1993-1997 to analyze and develop mechanisms for enforcing land use policies so as to control the magnitude and direction of landscape changes.

Inevitably vegetation cover monitoring is a crucial area for protecting soil and water resources. Hence, many studies have been conducted for monitoring of vegetation cover and it is observed that the methodology where RS and GIS techniques used is most reliable and fast. Propastin et al., (2008) in their study developed a monitoring system based on RS and GIS technology which was used effectively for the assessment of degradation or improvement of vegetation cover.

Crop and area suitability or land capability are interrelated. To identify the suitable areas for specific crop is not an easy task, for this purpose many factors are taken into account. Climate and soil type are two major factors that needs to be considered. In the study conducted in Mexico for delineation of suitable areas for crops, an approach based on multi-criteria evaluation was used to identify those areas

which were suitable for the production of potato and maize crops. For this purpose imagery of year 1996 was used and supervised classification tools were implemented to achieve land use land cover classification and match suitable areas for growing potato and maize (Ceballos-Silva et al, 2003).

Forest loss and degradation has become a big issue today, the effects of which vary from soil loss, sedimentation in rivers to climate change. Therefore forests management has become a very important issue and it is being felt that a mechanism must be available to monitor the depletion of forest in real time, the only technology that has the aforesaid solution is a remote sensing and GIS based customized application. In forest monitoring and assessment the primary objective is to know what and where the forest area exists, GIS sharply addresses such issues.

In Nepal, middle hill region, a study was conducted to measure the land use (specifically with respect to forest) changes over 14 years period (1978-1992). This was a very important and critical study due to its extensive coverage of an area of 543 Km^2, GIS and remote sensing technology was executed to conduct this study and aerial images were used for GIS analysis. The study proved quite useful in forest management and protection. This study demonstrated the importance and involvement of GIS/RS technology in detecting changes in forest resources whether temporal or spatial (Gautam et al., 2002). RS and GIS technologies can also help in monitoring afforestation efforts and their success. The technology has proven their worth to produce accurate, quick and reliable products that are highly useful for planning, mapping and analysis of forests and their types. Moreover, in the area of fire susceptibility which is the major threat in tropical areas geospatial technology is being used to identify fire susceptible forest areas. Further, GIS technology is being used

successfully for planning and allocation of fire suppression resources and early warning (Pradhan et al., 2007).

Forest encroachments can also be monitored through remote sensing and GIS. Very often to improve the economic growth that creates jobs, increases per capita income, attracts labours, new economic activities encroach upon forest land. In addition, forests are also removed as a result of demand for plots for the residential purpose. In developed countries provision of residence is the main cause of forests loss along with their conversions into zones of economic activities (Bradshaw and Muller, 1998).

With the increase in population and economic activities, water resources have become very important and critical for human survival. Increase in population growth, vegetation demand, industrialization, cheap power generation and many other anthropogenic factors are demanding for more and more water resources/reservoirs.

The main theme/objective of the management of irrigation water system is to achieve efficient and effective use of water resources as well as optimal production of crops. There is no doubt that water is a valuable resource as well as the management of water resources is a complex task. In this regard watershed sector is a very critical area; in natural resource conservation/management perspective the best considered globally accepted approach is integrated watershed management. Gosain et al (2004) express that a large number of guiding principles are involved in watershed management such as integrated development and conservation of natural resources, as well as social factors, and the use of GIS can be very helpful in this. In fact, digital elevation model that is an important feature of geographical information system can be very effective and most appropriate in watershed management.

Many studies have revealed that integration of remotely sensed data and geographical information system also provides the basis for determining those critical areas where vegetation on river bank is essential to check river bank erosion and for the management of river water quality. One such study was conducted on Iowa River watershed in USA. In that study remotely sensed data (TM)/ images were used for the classification of land cover and GIS techniques were used to develop and analyze riparian buffer zones (Narumalani et al, 1997). Application of GIS and its integration with remotely sensed data can help greatly in providing the mechanism for the selection, analysing and implementation of riparian buffer zones.

Many other studies like Hedges (1999) admit that GIS is a powerful tool for assessing the environmental and social impacts of groundwater developments. Natural Resources Management Organizations not using GIS/RS will face lots of problems in future and will be at a great disadvantage as compared to the ones using these (Patra and Pradhan, 2005). Bracke (2008) declare that GIS is one of the greatest and amazing tool that have the ability to pull geospatial data together from different areas and different sectors of the information universe. Muthanna and Amin (2005) say that GIS is an efficient and effective tool in irrigation planning and it can also be useful in identification of crops, classification and even for assessing crop suitability. Frederiksen (2008) focus on water, that it is a major sector that effect the land use such as irrigated agriculture, dams, urban developments and forest etc and it is necessary to integrate elements of land use and development plans in water management and planning. The use of GIS and RS could be quite effective for the same.

To date, Remote sensing and GIS has gained substantial importance in many fields whereby these are being used as a research and monitoring as well as planning and management tools. Remote sensing technology has a bundle of dynamic ancillary qualities, like in water resource perspective, it can provide dynamic information to manager, policy makers, researchers, consultants and to the general public on water quantity and quality, the information that can be crucial for planning, performance assessment, water allocation, impacts assessment, health, and environment related fields (Bastiaanssen et al, 2000).

Additionally, Detection and estimation of information is the key feature of RS/GIS technology in flooded areas. It provides information on the movement of flood water and its volume which are extremely important in early warning, forecasting and appropriate disaster management planning. GIS technology performs this crucial task with the help of DEM model, which has the ability to estimate and provide information on the flow of water (Brivio et al, 2002).

The changes induced by human being in land use and land cover are critical factors in bringing change in global environment. Changes in biophysical state of the earth are represented as land cover while changes in land use are the result of socio economic, and political influences (Nagendra et al, 2004). In both cases it is the human activity which causes the change and RS/ GIS helps in detecting how much change has taken in place in both spatial and temporal perspective.

In assessing and estimating type, variety and extent of land cover change, a combination of satellite remote sensing and geographical information system can be very effective. Physiographical attributes of the earth surface refer to land cover data

that range from tropical forest to bare rocks. Remote sensing and GIS can help in identifying and conserving land cover and land uses that are vital for environmental protection. Moreover, through continuous monitoring it facilitates to measure and detect those environmental changes that are harmful to human health and well being (Kerr et al, 2003).

A prime factor of environmental change is the amendment of natural land-cover due to human land uses. Land is being modified at a rate, spatial scales and magnitude due to human activities that is unacceptable (Turner, 1994). Therefore, their control is essential through land use planning (Verburg et al, 2002).

Land use/ land cover is affected by socio economic necessities and rapid growth of population and resulting of this pressure improper and uncontrolled land use/land cover changes. Yang and Lo (2002) endorses the ability of remote sensing and GIS system for the producing of accurate land use/land cover maps and change statistics.

To quantify the type, location and amount of land use changes multi temporal and multi spectral data is used, which is acquired by Remote sensing technology and GIS. In combination, they provide the feature for displaying/presenting, storing and analyzing the digital data for the purpose of change detection and control (Wu et al., 2006).

RS and GIS is also helping substantially in planning and management of cities. Lopez et al, (2001) point out that urban planning can be based on data, which are acquired using airborne images with the support of renowned geographical

information system technology. RS and GIS can also help in monitoring and management of urban growth and planning of utilities and services.

Terrain model is an important tool that is being used extensively by land developers and architects. Moreover, terrain model is also being used extensively for better water management, albeit water quality is a major concern for the health therefore, better management of water is essential. Accordingly, In GIS environment different tools, different file format are used for specific purposes like stereo lithography file is used to make a physical terrain model (Agrawal, 2006)

Remote sensing and GIS technology is also being used for extraction of building features without physical interaction. Lari et al, (2004) proposed model using high resolution satellite imagery for automatic extraction of building features.

Turner et al, (2003) highlight challenges faced by conservation biologists and ecologist lacking in technical expertise related to GIS and remote sensing. They argue that these specialists are willing to incorporate this sophisticated technology into their work but need appropriate training. He also explains that in recent times many evolutionary biologist, emerging ecologists and conservation biologist have started to use combination of GIS and Remote sensing technologies in their professional work.

Bastiaanssen et al., (2000) state that data acquired by Remote sensing, and information extracted by geographical information system can be significantly helpful for spatial planning purposes. They are very effective and help substantially in developing large scale irrigation projects, area development schemes, residential

developments, demarcating conservation areas, land reclamation and biomass development projects etc.

GIS may also be used in facilities management, where location factor matter in planning and management operations (Han S.S. and Yu M.S, 2001). Foody (2008) endorses that in biodiversity GIS has provided, a range of data on environmental properties especially through remote sensing. Ramli et al. (2005) considers GIS as becoming a necessity in most scientific disciplines particularly environmental studies. In human settlement studies GIS can provide different type of geographic data, like streets, population, income levels etc (Forcht, 2000). In addition Snow et al. (2007) state that

> *"GIS technology serves as a valuable tool by which communities can benefit by participating in a mechanism to enhance predictability as they incorporate this information into shared decision making for sound and sustainable environmental management" Snow et al., (2007).*

Jensen and Cowen (1999) differentiate the temporal resolution between two different environmental hazardous areas to show the effectiveness of RS/GIS in hazard monitoring and management. They also demonstrates the importance of RS / GIS in highlighting zones or areas of critical environmental issues like endangered species, land surrounding treatments plants, wetlands, parks, and the land used for watersheds which provide potable drinking water. They also point out that those areas which are relatively stable require monitoring every one to two years while for extremely sensitive areas where change happens speedily must be monitored one to

six months and such monitoring can only efficiently be executed through remote sensing / GIS techniques.

Climate change is to effect impacts on resources, land use and occurrence of natural hazards and calamities. Remote sensing and GIS provide very useful tool for assessing these impacts for example on glacier melting, water availability and land use as well in developing coping strategies for the same. Dale has provided information on impact of climate change on land use and on developing management responses (Dale, 1997). Sharm a (2001) states the importance of RS and GIS in developing a response system in natural disasters.

Remotely sensed data whether through satellite or airborne provide valued detail about the change that is taking place on earth's surface whether as a result of climate change or other factors. Nevertheless extraction of information from the features at the earth's surface provides an excellent source for environmental change and transition (Zhang et al., 2002).

Moreover, in three dimensional perspective GIS technology has a unique and versatile feature in developing maps in the shape of Digital Elevation Model (DEM) that could be helpful in monitoring, analysing and predicting the natural resources as well as man made resources like Agriculture, water bodies and forest etc. Billa et al. (2004) strongly support this argument that "The aptitude of Geographical Information System (GIS) to develop three dimensional (3D) topographical maps and terrain models in the form of digital elevation models (DEM) and digital terrain models (DTM) are useful in flood analysis and assessment".

Spatial technology now is also being used increasingly in natural hazards monitoring and analysis, even for prediction in some extent. Additionally this technology can be used to provide rapid and continuous information for environmental monitoring, flood forecasting, monitoring forest fires and landslide hazards classification and assessment (Mansoor et al., 2004)

All over the world, where effective and timely disaster analysis and relief is executed, the role of remote sensing and GIS is predominantly there. In other words, GIS and RS have revolutionized the activities of disaster forecasting, analysis and relief (Eveleigh et al., 2006).

The casualties and damages caused by land slides are very extensive. Shape of the earth is changed by many processes and one of the processes is Landslide that is a major cause of change in the infrastructure built on earth. Land slides particularly force exerted by the earth, debris and rocks moving in land slides can crush the people, infrastructure, animals and other creatures. Land slides can also cause of disruption and dislocation of objects. Elaborating on this Shafri et al, (2010) state that land slides are major cause of dislocation of objects like severing of telephone, electricity, gas and water pipelines, destruction of bridges, roads and railway lines etc.

Landslide incidents and events happen in many countries causing serious environmental as well as economic damage. It is very important to have the intelligent, reliable and efficient system for early warning system as well as for post landslide planning and management, so that losses could be reduced. Landslide warning system for sustainable development can be generated using integration of GIS and Remote sensing data (Shafri et al, 2010). Monitoring by earth observation

satellites is quite common now. Images acquired by the satellites can now provide more accurate, reliable and timely information base on multiple bands with high resolution data.

Syed Omer et al., (2004) elucidate that combination of GIS with remotely sensed data greatly facilitate in identifying and demarcating landslide areas. With development perspective in mind, Kopke (2005) pointed out that creation of vulnerability to land slides or any other hazards as a result of any future development can be assessed and evaluated through GIS/RS. Moreover, appropriate steps can be carried out to protect the area from falling pray to environmental hazards in case of land use change in that area.

Spot5 and LANDSAT7 images can be used for large size landslides and small size Aerial images for small slides. Small scale landslide can also be measured through images obtained from Quick-bird and IKONOS satellites, which provide better resolution that is very near to Aerial photographs. Three steps are involved in land slide risk reduction - detection, evaluation / analysis and monitoring. Detection and monitoring can be done at remote sensing end while evaluation / analysis are done by GIS. Detection includes two steps: recognition - "Is it landslide or something else?" while the second one is "Classification" what type of landslide it is? (Mantovani et al., 1996).

Showalter (2001) elucidates, several studies note that detection, identification, mapping, surveying and monitoring of existing hazards as well as the effects of hazards has largely been practiced using remote sensing technologies. He also expound the importance of remote sensing in terms of disaster management - damage

assessment and planning as well as in providing emergency services with information for preparation, early warning, response efforts and relief.

One of the major objectives of such activities is to facilitate in decision making / policy making, additionally, integrated use of GIS and Remote sensing data can be helpful to provide/identify the area where land slide can happen.

The main focus, in this study is on the use of GIS/RS on mapping of agriculture, water bodies and forest in Pakistan's Punjab province. Managing agriculture, water bodies and forest sustainability is the main concern in almost every country of the world, and geographical information system (GIS) / remote sensing (RS) are gaining importance as effective tools in sustainable management of agriculture, water and forest resources.

CHAPTER THREE

3.1 METHODOLOGY

Geographical information system (GIS) and remote sensing (RS) were used to map the land use / land cover classification in three major and critical areas (Agriculture, Water bodies and Forest) in Punjab province of Pakistan. For this purpose topographic sheets were used as the base maps and satellite images for analysis of the information.

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Land use/land cover mapping of an area is a complicated operation. To accomplish this task landsat ETM images as well as topographic sheets were obtained from Ministry of Environment, Government of Pakistan. Topographic sheets (Base map) were scanned and digitized using ArcView software. Furthermore, these sheets were loaded in GIS software for geo-referencing. Side by side, the landsat ETM satellite images were geo-referenced and the rectified maps were mosaiced to amalgamate using Erdas Imagine software. Subsequently, mosaic of i mages was superimposed on rectified base map.

The next step was the pulling of Punjab province out of full mosaiced image of Pakistan and three major land use/land cover classification were carried out separately and superimposed on Punjab province. Finally, measurement of each data layers was performed separately.

Basically, three softwares were used in this study:

- ArcView
- ArcGIS
- Erdas Imagine

ArcView is used for displaying and subsequent processing and enhancement of the image. It is also used for carving out the Punjab Province from the image of Pakistan.

ArcGIS is used to compliment the display and processing of the dada.

Erdas Imagine is used for developing the mosaic.

Constraints and limitations:

This study on land use/land cover had one major limitation that relates to data, that was collected from different sources and there was some difficulty in data compatibility, which was resolved through discussion with the data providers.

CHAPTER FOUR

4.1 DATA ANALYSIS

The results of land use/ land cover classifications in the form of maps and tables in the following. Table.1 given various classifications of land use/land cover and their subclasses that were identified for their study on the Punjab province.

Table 1. Land use/Land cover classification of three categories- Agriculture, Forest and Water bodies

S.No.	Landcover/Landuse	Sub-classes	Description
1	Forest	Conifer forest	Pine forest
		Broad leaf forest	Tree cover, woodland
		Scrub forest	Forest type (height 2-5m)
		Riverine forest	forest like bela along the river
		Mangrove forest	Coastal forest
		Tree plantation	Man-made forest
2	Agriculture land	Orchards	Fruit trees
		Irrigated Agriculture	Canalirrigation, snow/glacier melt and well irrigation
		Rainfed Agriculture	Barani land
		Rod-kohi Agriculture	Spate-hill-torrent irrigation
3	Water bodies	Water bodies	Lakes, rivers, reservoirs

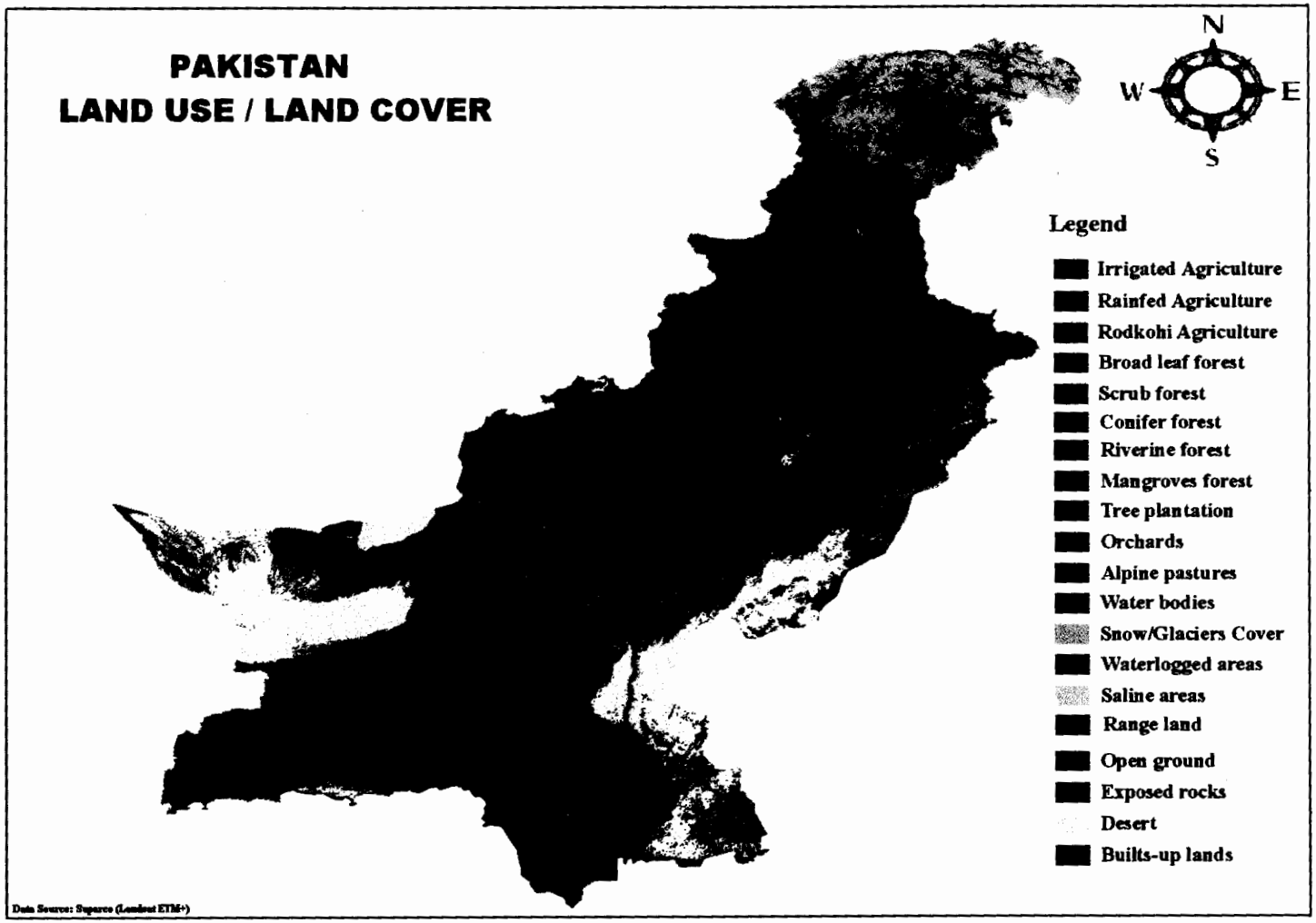

Figure 1. Pakistan: Land use / Land cover

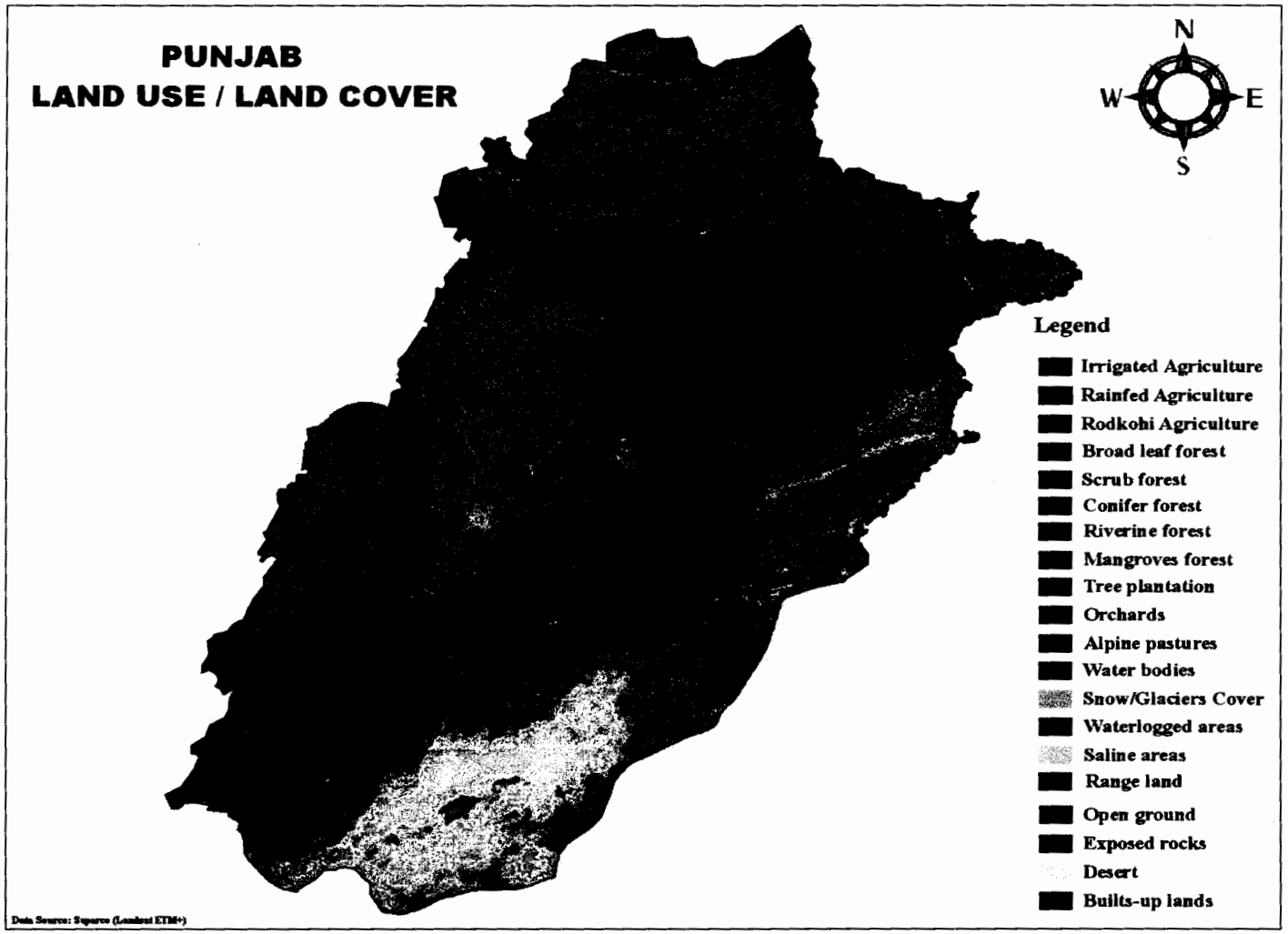

Figure 2. Punjab: Land use / Land cover

Landsat ETM Data was acquired for the study to map land use/land cover. The geographic coordinate system using WGS84 parameters was used in geo-rectification of 67 image scenes. Image analysis was performed using a hybrid analytical approach (visual and digital). For image classification, unsupervised classification was used initially to develop classes identified by the computer on the basis of similar spectral characteristics of the group of pixels. It helped in defining more specific classes for supervised classification method. In supervised classification, suitable band combination was used and training-sample sets were selected from known areas on the image to form set of signatures for classification as recorded in table 2 and Fig 1&2.

Table 2. Pakistan: Land use/Land cover

S.No	Pakistan Land use/land cover
1	Agricultural land
2	Forest
3	Water bodies
4	Built- up area/land
5	Bare Soil
6	Desert
7	Exposed rocks
8	waterlogged and saline land
9	Rangeland
10	Snow/Glaciers

Table 3. Punjab: Land use/Land cover

S.No.	Punjab Land use/land cover	Area (hectares)	Percentage
1	Agricultural land	10129.1	49.10
2	Forest	841.3	4.08
3	Water bodies	173.7	0.84
4	Built- up area/land	189.2	0.92
5	Bare soil	1709.5	8.29
6	Desert	1780.2	8.63
7	Exposed rocks	313.1	1.52
8	Waterlogged and saline land	122.3	0.59
9	Rangeland	5370.1	26.03
	Total	20628.5	100.00

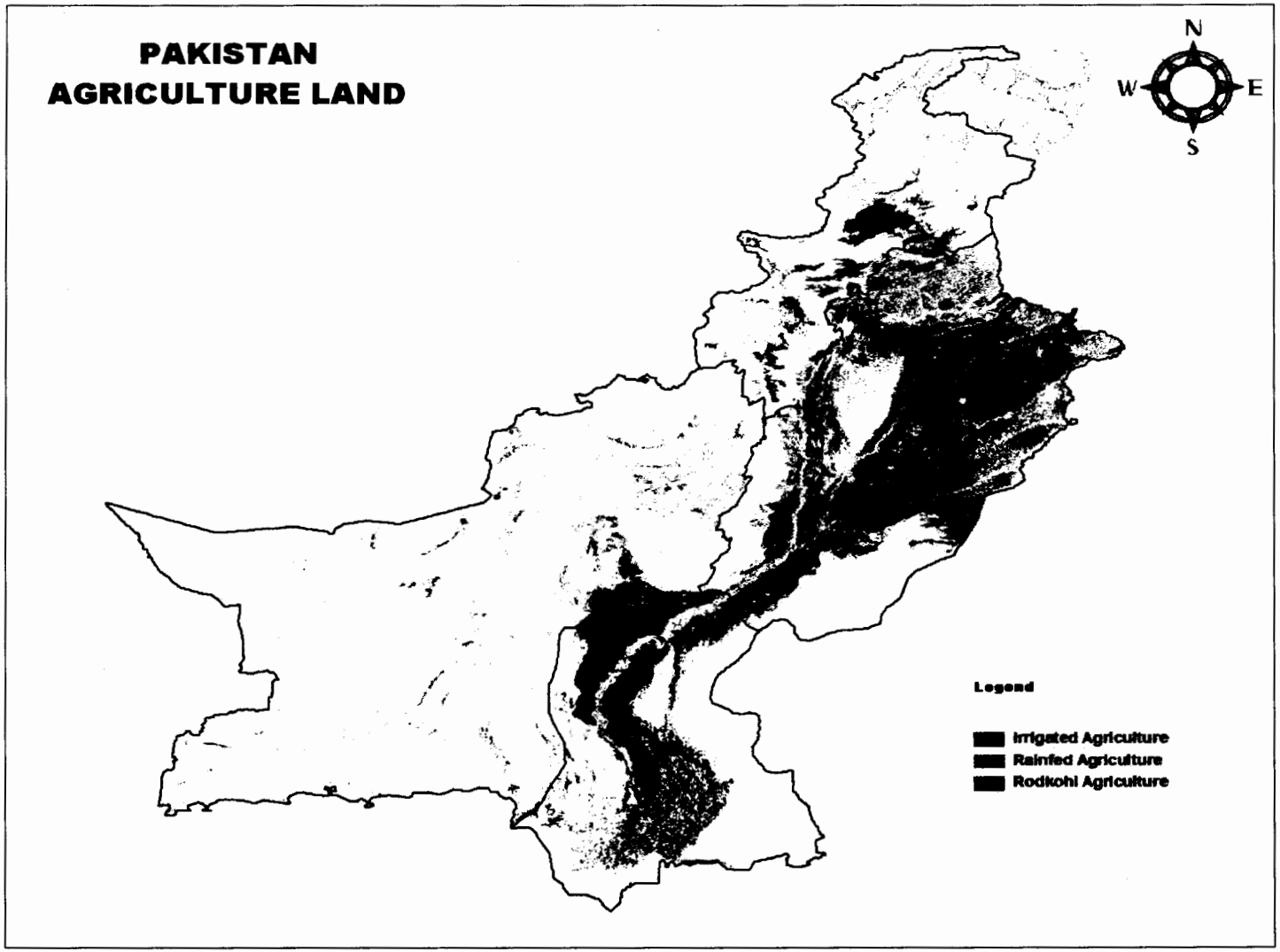

Figure 3. Pakistan: Land use / Land cover (Agriculture)

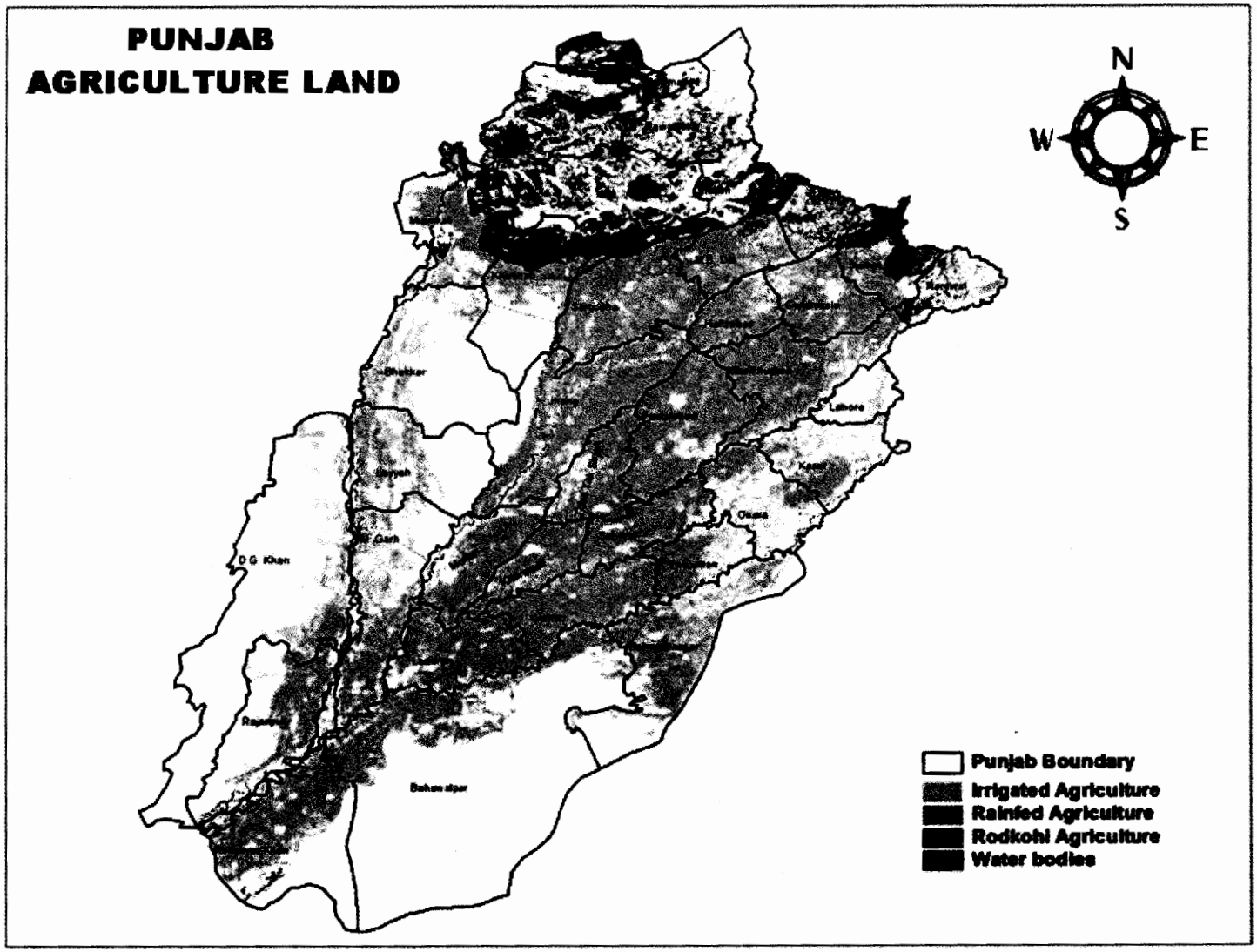

Figure 4. Punjab: Land use / Land cover (Agriculture)

4.2 Land use/Land cover (Agriculture)

Agriculture constitutes the largest sector of Pakistan's economy. Majority of the population in the country, directly or indirectly, depends on this sector. It contribution in Gross Domestic Product (GDP) is about 24% and it also accounts for half of employed labour force and is the largest source of foreign exchange earnings (Federal bureau of statistics, n.d). The food security in the country is dependent on this sector. Realizing its importance policy makers and planners are always keen to have reliable statistics showing various types of agricultural land use – cropped as well as area and production of agricultural crops well in time to assess the food situation in the country.

Among provinces, the leadership of the Punjab in cultivated area is based upon the vast alluvial plains and extensive irrigational facilities. Baluchistan, on the other hand possessing the largest land area has the smallest cultivated land due to rugged topography, intense aridity and limited irrigation facilities. Sindh and NWFP occupy third and fourth position in terms of land area respectively. The proportion of cultivated area in Sindh is comparatively high due to presence of flat area or plains and available irrigation facilities. One notable feature of agricultural land use in Pakistan is its expansion. The area increased almost five times since independence. Almost half of the area 49.10% of Punjab province is under agricultural land use. Irrigated agriculture is predominant and is mainly in the area drained by the Indus River and its tributaries as shown in Table 4 and Fig 3 & 4.

Table 4. Punjab: Land use/Land cover (Agriculture)

Land use/land cover	Area in hectares	Percentage
Agricultural land	10129.1	49.10

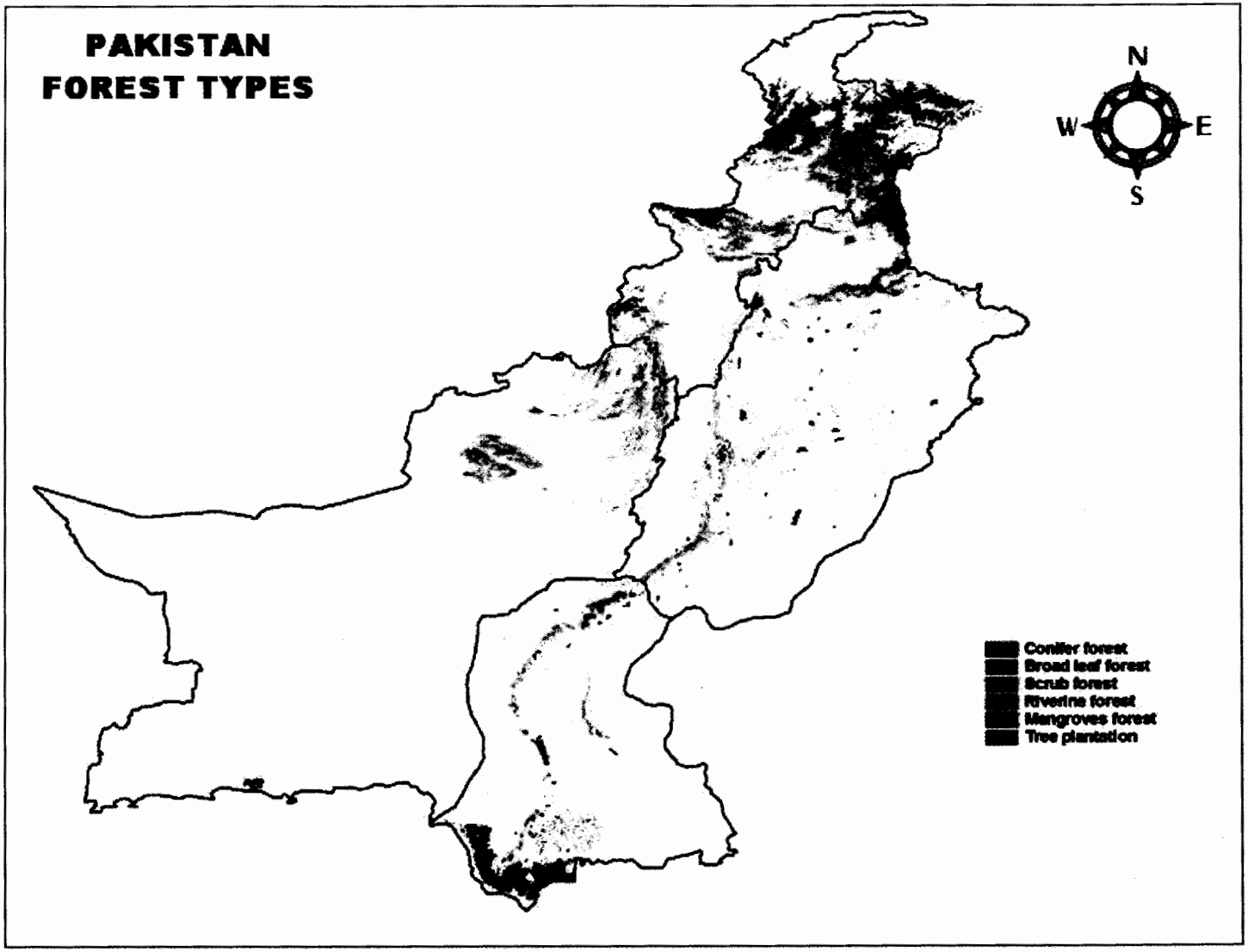

Figure 5. Pakistan: Land use / Land cover (Forest)

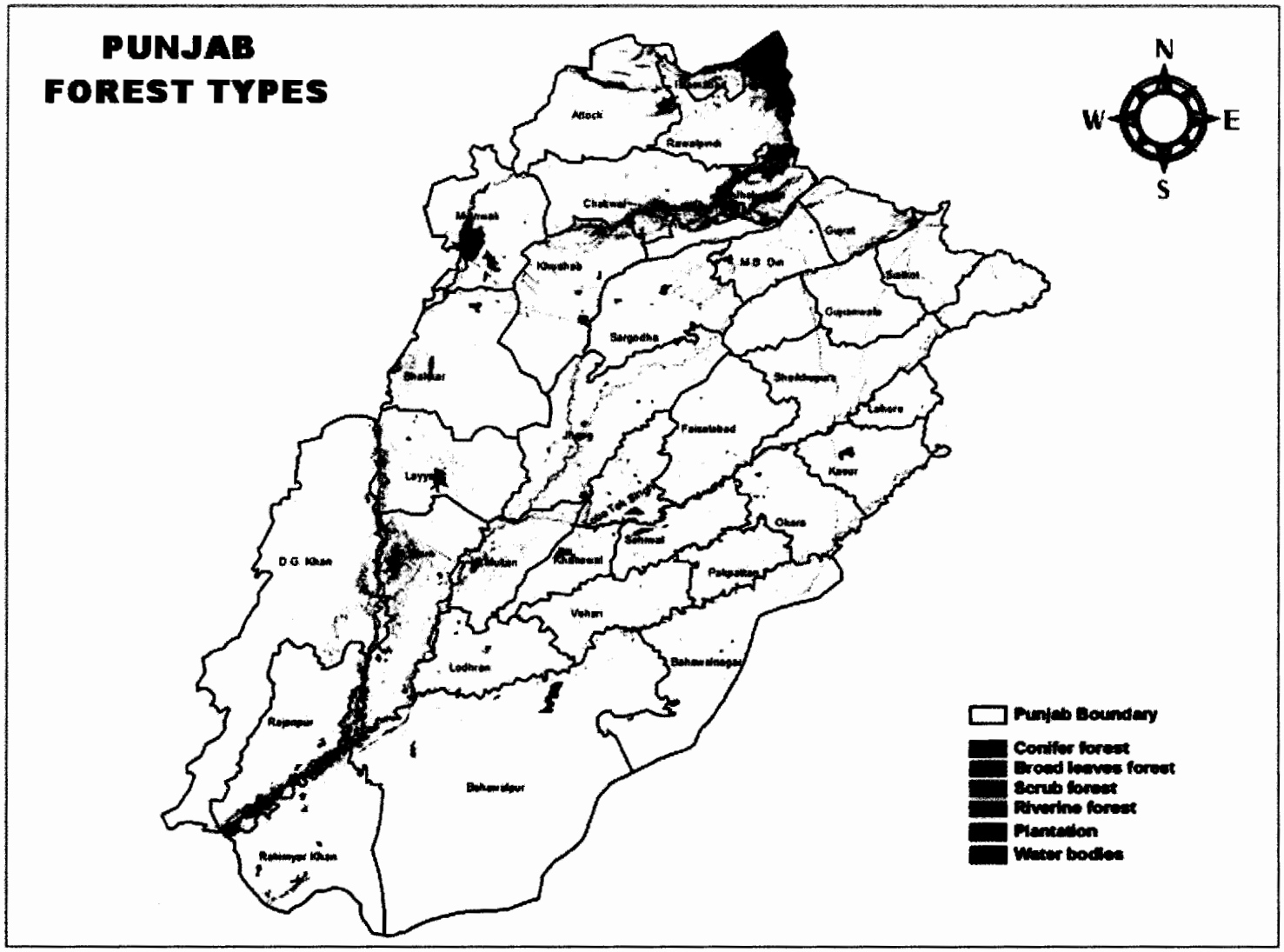

Figure 6. Punjab: Land use / Land cover (Forest)

4.3 Land use/Land cover (Forest)

Pakistan is poor in forest resources. Province wise NWFP has the highest percentage area under forests followed by Sindh, Punjab and Baluchistan. The major forest types in Pakistan include the coniferous forests, broad leave, Riverain, scrub and mangrove forests.

Conifer forest. Conifer forest is situated in eco-zones named sub tropical pine forests, montane moist temperate forests, dry temperate forests and subalpine/alpine forests. The range is found in Kashmir, Dir, Swat, Chitral, the Gilgit Agency and Hazara. The main commercial tree species found are Chir pine (Pinus roxburhii), Blue pine (Pinus wallichiana), Deodar (Cedrus deodara), Fir (Abies pindrow), Spruce (Picea smithiana) and Chilgoza (Pinus gerardiana).

Broad leaved forest. The tree cover often thorny with small evergreen leaves generally lie on hilly to plain areas of the country. It provides fuel wood for local consumption and forage for the domestic and wild animals. Some of the tree species include Phulai (Acacia modesta), Ber (Zizyphus mauritiana), Kachnar (Bauhinia racemosa), Kikar (Acacia nilotica), etc.

Riverain forest. These forests grow in the active flood plains of Indus river system from the foothills to Arabian Sea. They occur mainly in the Punjab and

Sindh. The main indigenous species are Kikar (Acacia nilotica), Jand (Prosopis cineraria), Obhan (Populus euphratica), Khagal (Tamarix articulata) and Shisham (Dalbergia sissoo).

Scrub Forest. These are generally semi-evergreen forests that exist in the dry subtropical zone on altitudes varying from 500 m to 1800 m. Covering a wide geographic range latitudinally, they are best sub-divided into southern and northern zones. In the southern zones they occupy lower valleys of Baluchistan, eastern or outer fringes of North Waziristan, and Khyber and Mohmand Agencies. In the northern zone, they occupy the lower slopes in the southern part of Chitral, Dir, Malakand Agency and Kohistan and parts of Upper Punjab. The characteristic trees are Olive or Kau (Olea cuspidata), Phulai (Acacia modesta), Amaltas (Cassia fistula) and Ber (Zizyphus mauritiana) etc.

Mangrove Forest. More or less dense forest; mangroves are of very low average height, often 3-7 meter high. They are found on the muddy coast of the Arabian Sea along parts of Sindh and Baluchistan. Extremely important as habitat for fish and marine life, these are being degraded due to intrusion of sea water, pollution and deforestation.

Plantations. Plantations especially the irrigated plantations constitute the most important man-made forest type in Pakistan. These are the main source of revenue earning in the Punjab and Sindh. Some of the main species grown are Shisham

(Dalbergia sisso), Mulberry (Morus alba), Poplar (Populus euramericana), Eucalyptus (Eucalyptus camaldulensis), Kikar (Acacia nilotica) and Bakain (Melia azedarach).

In Punjab the forest cover is limited, only about 4 percent. It is predominantly scrub forest (2%). Riverain and broad leave forests cover only 0.7% each. Forest cover 4.08% area of Punjab land as recorded in Table 5 and Fig 5 & 6.

Table 5. Punjab: Land use/Land cover (Forest)

Land use/land cover	Area in hectares	Percentage
Forest	841.3	4.08

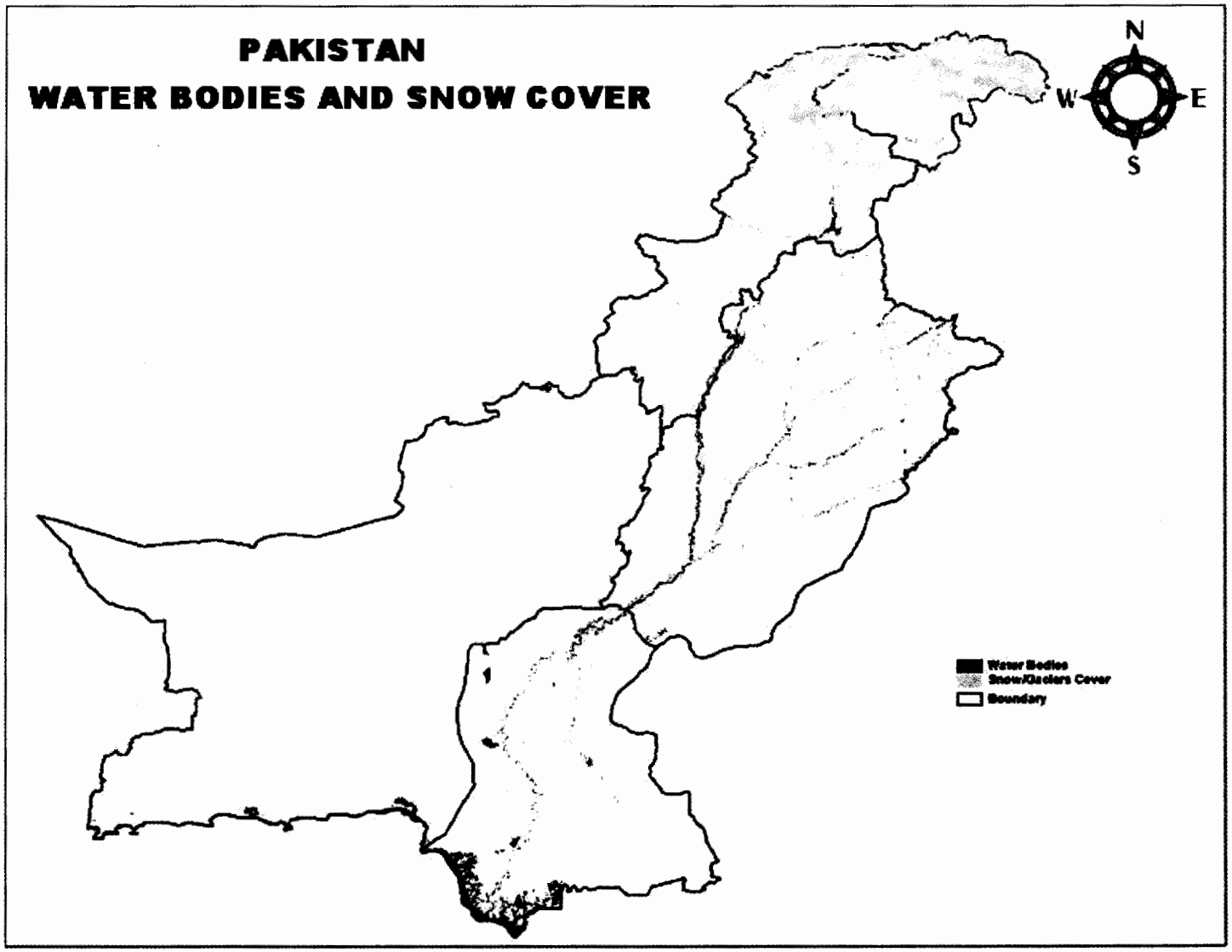

Figure 7. Pakistan: Land use / Land cover (Water bodies)

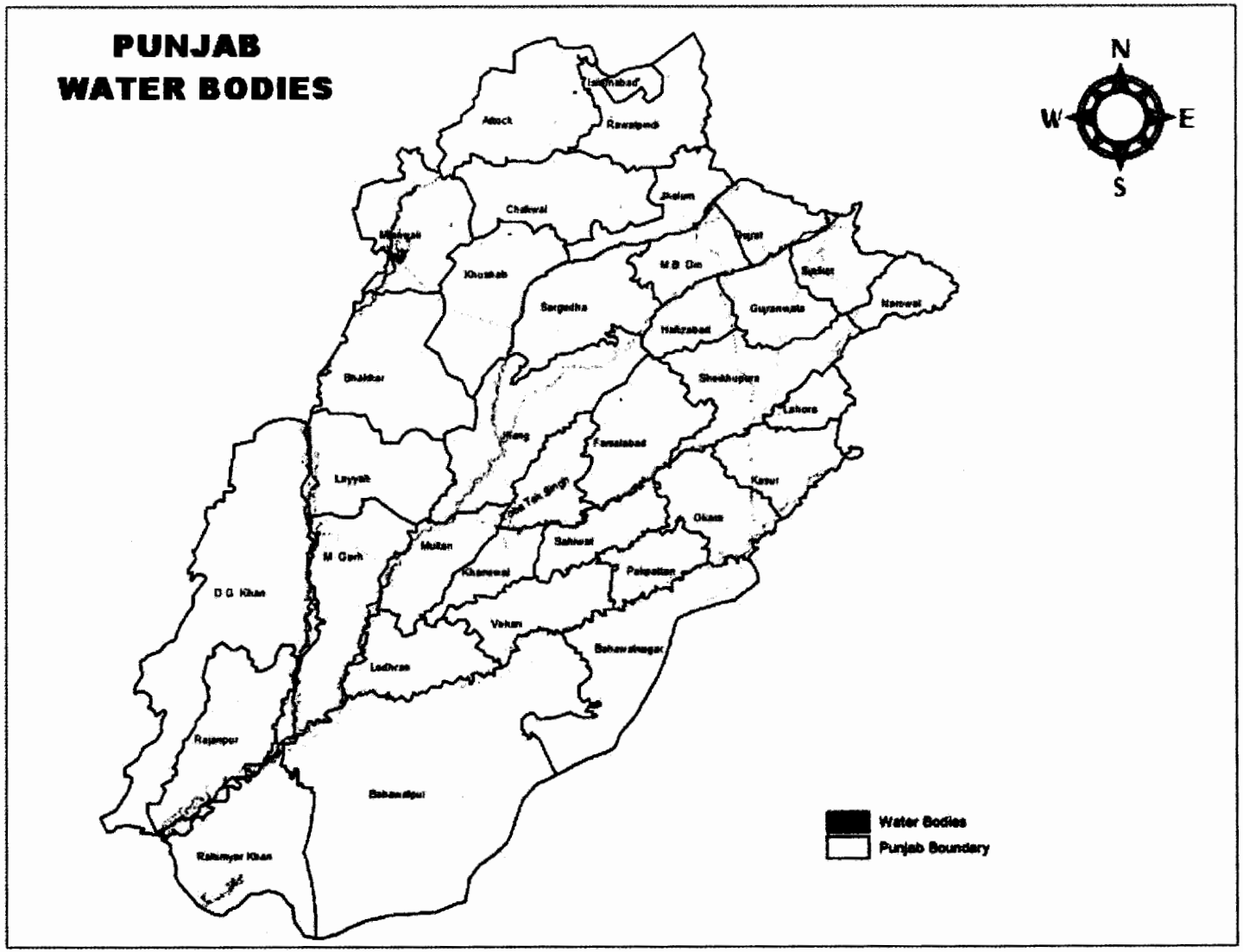

Figure 8. Punjab: Land use / Land cover (Water bodies)

4.4 Land use/Land cover (Water bodies)

Glaciers and snowfields feed the Pakistan's irrigation system, one of the biggest in the world. The largest and the longest river in Pakistan is the Indus River, which is also called the 'Lifeline of Pakistan', as the river and its tributaries are the largest water source in Pakistan. Around two-thirds of water supplied for irrigation and in homes comes from the Indus and its associated rivers. The tributaries of Indus River are Jhelum, Chenab, Ravi, Sutlej, Kabul, Swat and Chitral Rivers. Other tributaries include Astore. Gilgit, Gomal, Kurrum, Shigar, Shyok and Soan Rivers. Pakistan is also home to several natural and man-made lakes and reservoirs. Manchar Lake is the largest lake in Pakistan, which is also the largest lake in South Asia. The lake is spread over an area of over 160 square Kilometres. Furthermore, Indus, Chenab, Ravi and Sutleg rivers are major source for irrigation; huge area of Punjab land is irrigate through these rivers. So, regular monitoring of water resources is essential for effective planning and policy making. Moreover, Punjab water bodies cover area of 0.84% approximately of Punjab land. As recorded in Table 6 and Fig 7 & 8.

Table 6. Punjab: Land use/Land cover (Water bodies)

Land use/land cover	Area in hectares	Percentage
Water bodies	173.7	0.84

CHAPTER FIVE

5.1 CONCLUSION

Punjab, province of Pakistan, has seen a large unplanned growth and development activities in the form of human settlements, road construction, deforestation and many other anthropogenic activities since 1947. These unplanned development activities have caused a great loss to the national economy, as a result of inefficient utilization and loss of resources. To overcome the problems and issues GIS and RS sophisticated technology has been demonstrated as a mean to avoid such losses by capturing and processing spatial data for land use/land cover in the study area.

Since land use changes may occur rapidly, therefore it has become essential to provide information and data also at the commensurate rate so that decision making could also take place in time to exercise damage control. Tools like GIS/RS are very effective in providing quick information to assist in the process. This study has provided a case for utilizing optimum potential of land, by using GIS/RS technology It has shown that this technology is quite effective in mapping land use/ land cover and has several advantages over the conventional ground survey methods that are time consuming, labour and resource intensive and are also conducted infrequently. The research identified different types of land use/land cover focusing on agriculture, forest and water bodies in the Punjab province, which could be of substantial use to planners and decision makers at the provincial or district level, who can compare this

land use / land cover to land capability and potential and make efforts to optimize the land use/land cover.

With a growing population to feed and as a largest employer, agriculture sector and agricultural land use has great importance for Pakistan. Since sustenance of agriculture is dependent on land, water and biodiversity hence other uses like water bodies and forest also assume great importance. Fig.2 demonstrates clearly the linkage between agricultural sector and water bodies. Further, more comprehensive details about linkages between agriculture and water bodies can be visualized from Figure 4 and Figure 8 that express the interrelationships between agriculture and water bodies and their effects on each other. Other similar linkages exist between the quality of land and agriculture.

Unfortunately, still there is dearth of well organized land use/land cover data available to policy makers and researchers in Pakistan. This study has provided some information but this information is not static. It changes and there is a need to conduct similar studies on regular intervals to that land use / land cover change could be monitored and appropriate steps could be undertaken for promotion of optimal land use and control of undesirable land uses.

One undesirable change is conversion of prime agricultural land into urban settlements. It is also recommended that urbanization must not be carried out on rich agricultural areas. Furthermore, conversion of forest land into agriculture land causes environmental degradation aggravating climate change and promoting soil erosion. Therefore deforestation should also be checked. In Addition, proper identification of

suitable locations of reservoirs like lakes, dams can be carried out using GIS/RS technology using digital elevation models (DEM). This research has also demonstrated the need for the development of spatial information system using GIS and RS to help in planning and decision making for sustainable development.

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