Mapping and temporal analysis of sowing trend of sugarcane crop, with the help of remotely sensed data in Punjab, Pakistan

By

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CERTIFICATE

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DEDICATION

To

My Sweet & Loving Family, especially …

To my father for moral support, strength, encouragement, to my wife for her unconditional love and to my mother for making me believe that my fate lies within me and to make me brave enough to face it.

Thanks for understanding the stressful moments I had, for the prayers and support to overcome them and for all the joy you have brought to me.

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All praise be to ALLAH the Almighty the Exalted, the Lord of all the worlds. It is undeniable that all manifestation of nature bears eloquent testimony to the fact that Allah is the creator, the Maintainer and the Regulator of the world. He makes laws for the evaluations of things and sets them on the path of perfection. Almighty Allah who bestows and blesses knowledge, technology and scientific ingenuity to man through experimental research and remarkable deduction to ponder over the forces of nature. In the first place, therefore, I express my utmost thanks to Almighty Allah the omnipresent and the creator of the worlds, who has endowed us brain and instable instinct construction of knowledge and body to accomplish our work in the form of this project report.

"No doubt, appreciation is prior to acknowledgement; quality of the latter is superior to the essence of the former."

I offer my gratitude to the last Prophet MUHAMMAD (Sallallaho Alaihe Wasallam), who has given the lesson of LOVE, HUMANITY, PARITY, and JUSTICE and also broke the cage of servitude through His golden sayings; to seek knowledge is obligatory for every Muslims.

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I express my sincere thanks to respected Dr. Salman Atif-IGIS, for his worthy guidance. I have always looked up to him for guidance in any problems I faced in my work. I feel immense pleasure to appreciate and thank Dr. Muhammad Ashad-IESE and Dr. Muhammad Azmat -IGIS for their kind and timely guidance to get my goal done.

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Tahir Saeed

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ABSTRACT

This paper presents a method based on the use of remotely sensed data to identify and map sugarcane fields. It identifies the sowing trends adopted by sugarcane growers from the year 2008 to 2014 and also determines and analyses the socio-economic causes behind such trends. A field survey was carried out in two districts, Sargodha and Okara, for ground truthing the exact location of major crops. Field survey data and NDVI images created from data from Landsat 7 and 8 data were used to determine the appropriate time and range of NDVI values required to map sugarcane fields. NDVI images were then classified into sugarcane and non-sugarcane areas. Sugarcane sown areas in 21 districts of Punjab over the years 2008 till 2014 were analysed to obtain sowing trends. The sown area identified through remotely sensed data was then compared with statistical data obtained from the Government of Punjab (GOP). Overall, similarity among the two data sets was approximately 90%. Sugarcane sown area mapped from remotely sensed data was also compared with ground truth data collected in the field for three districts i.e. Faisalabad, Hafizadad and Sargodha. The overall accuracy for these districts was 79%, 72% and 80 % respectively. A sowing trend map was created from the sugarcane sown area estimated from remotely sensed data. The results showed that out of the 21 districts examined, sugarcane area over the years 2008 to 2014 decreased in 6 districts, increased in 5 districts and remained consistent in the rest of the 10 districts. A comprehensive questionnaire was designed in the local language and distributed amongst farmers to investigate the socio-economic causes affecting the sugarcane sowing trend. Results indicated that profitability of the sugarcane crop is at par with crops like wheat, rice and cotton. 100 % of the farmers were dissatisfied with the government imposed support price of sugarcane as well as the attitude and

behaviour of sugar mill staff. One of the main reasons for decreasing trend in sugarcane sowing in six districts was deduced to be low crop prices and delayed payments. While the GOP recommended support price for sugarcane during 2014 was Rs 180/- per 40 kgs, some sugar mills, particularly those in the districts where sugarcane area is decreasing, are only paying Rs 176/- per 40 kgs on average. Payments to farmers are also being delayed for an average of nine months.

The method presented in this paper for identifying sugarcane areas can be helpful for both farmers as well as sugar mill owners for effective and timely monitoring of sugarcane crop vs their requirement in their respective feeding areas.

Chapter 1

INTRODUCTION

Sugarcane is tall perennial crop which is cultivated generally in subtropical regions of the world between latitude 36Nº and 31Sº.The sugarcane has high content of sucrose between 10-18% and high content of fiber upto 10- 15%. It takes 10-24 months for sugarcane to become ready for harvest (Abdel Rahman & Ahmed, 2008). Sugarcane is grown in warm tropics and give best yields where rainfall is heavy interspersed with bright sunshine. It is temperature sensitive and its growth stops when temperature exceeds 35Cº, the optimum range of temperature is between 20 Cº to 30 Cº. It requires minimum of 600 mm of annual rainfall (Qureshi & Afghan, 2005). There are three major stages for sugarcane growth sprouting and tillering, stalk growth and maturation (Begue et al., 2010). The maturation occurs when soil water content is low, temperature is decreasing. The crop is harvested when it is sufficiently matured and ripened. Sugarcane is grown mainly for production of sugar but there are other by products which can be obtained from sugarcane. These includes bagasse, molasses, fiber cake and cane wax. Alcohol is also produced from sugarcane in some countries like Brazil (Xavier, Rudorff, Shimabukuro, Berka, & Moreira, 2006). Sugarcane is also used as raw material for production of gur and chipboard as well.

There are 107 countries in world which grow sugarcane over an area of 20.42 million and a total production of 1333 million tons .Sugarcane area and productivity and area varies from country to country. Pakistan, India , Brazil and China accounts for 50 % of world production (Qureshi & Afghan, 2005) . Sugarcane is one of the major crop of Pakistan. Sugarcane crop has shorter growing cycle than normal in Pakistan. Its sowing usually starts in February and it is harvested after exactly one year. A total of 2.63 Million Acre area in Pakistan is under sugarcane crop. A total of 2.63 Million Acre area in Pakistan is under sugarcane crop. Province wise distribution of sugarcane is as follows. Punjab 1.59 Million Acre, Sind 0.59 Million Acre, Khyber Pakhtunkhwa 0.47 Million Acre, Baluchistan1.73 Acre (Agriculture-Census-Oganisation, 2010) .(Table 1.1)

Table 1.1. Province wise distribution of sugarcane

S/No	Province	Sugarcane Area (Million Acre)
1	Punjab	1.59
2	Khyber Pakhtunkhwa	0.41
3	Sindh	0.63
4	Baluchistan	-

1.1 Purpose of study and justification

Pakistan is an agricultural country with agriculture based economy. The contribution of agriculture towards GDP is 24 % and employed labour force is 44.7% of the total (PBS, 2015). Sugarcane is considered as important cash crop in Pakistan as sugar industry is second largest industry of Pakistan. Therefore it is far more important to know the sown area, yield, health condition of sugarcane every season for better management of the crop and the sugar industry.

Presently different techniques are being applied to estimate the area sown and yield of the sugarcane crop. These techniques mainly include field surveys, sample surveys by different departments, Girdawar survey by Patwaris and also opinion surveys. Remote sensing can serve a successful tool to monitor and determine the cropped area. In this research a study will be carried out to exploit the potentials of remote sensing to detect and map sugarcane fields using remotely sensed data. Sowing trend for sugarcane crop will be identified from temporal analysis of sugarcane cropped area from year 2008 till 2014 using remotely sensed data. Also the socio economic reasons for sowing trend of sugarcane crop will be determined. In this way some challenges and problems faced by sugarcane growers will be understood in context with Punjab, Pakistan. The study will also help the sugar mills timely and effective monitoring of the sugarcane area and yield in their respective feeding areas.

1.2 Research objectives

The Overall objective of the study is to identify and map sugarcane fields using remotely sensed data. The study will also identify the sowing trend for sugarcane crop from year 2008 till 2014 in Punjab, Pakistan and determine social and economic factors behind the trend.

In order to achieve the main objective following sub objectives are to be achieved

- Development of technique to identify and map sugarcane fields using Remotely sensed data
- Identify social reasons for sowing trend of sugarcane
- Identify economic reasons for sowing trend of sugarcane

1.3 Research Questions

- What is general perception about sowing trend for sugarcane in Pakistan?
- What are the different techniques to carry out agricultural surveys in Pakistan?
- How remotely sensed data can be helpful and being used in other countries to map different crops?
- What is the impact of support price on sugarcane growers?
- Comparison earnings from major crops with the earnings of sugarcane?

First two questions were answered by doing research on internet and exploring the existing literature. Finally, the remaining three questions were answered by doing the actual experiments on remotely sensed data and carrying out field surveys in different parts of study area.

1.4 Scope

The research deals with two main subjects; Understanding the potentials of remote sensing in identifying the sugarcane crop and mapping the sugarcane fields. The research also shows the sowing trend adopted by farmers for the last seven years and socio-economic reasons forcing the trend adoption. Data quality issues are within themselves, a complete problem and require specific methodology to solve so they are out of scope of this research.

1.5 Considerations and Limitations

As far as known here limited research has been carried out to map the sugarcane fields using remotely sensed data. Although some researchers have published their work focusing on economic analysis of sugarcane crop as it is the cash crop but there is a potential to study the remote sensing part of it and also the sowing trend over the years. Following were the limitations

- No existing digital or paper maps of existing sugarcane fields were found to compare maps generated through remotely sensed data
- There is no specific method available for mapping and area calculation of different crops in Pakistan

1.6 Expected outcome

This research will give us the maps of sugarcane fields for Punjab, Pakistan from 2008 till 2014. It will also give us the trend adopted by farmers with regards to sugarcane in last seven years. Socio- economic causes forcing the farmers to adopt trend will also be evaluated during research.

Chapter 2

LITERATURE REVIEW

The current study aims to understand the socio-economic causes of the sowing trend for sugarcane crop which is the cash crop in Pakistan and 65 % of its production is in Punjab Pakistan.

2.1 Sugarcane Phenology

Sugarcane is tall perennial crop which is cultivated generally in subtropical regions of the world between latitude 36Nº and 31Sº.The sugarcane has high content of sucrose between 10-18% and high content of fiber upto 10- 15%. It takes 10-24 months for sugarcane to become ready for harvest (Abdel Rahman & Ahmed, 2008) . Sugarcane is grown in warm tropics and give best yields where rainfall is heavy interspersed with bright sunshine. It is temperature sensitive and its growth stops when temperature exceeds 35Cº, the optimum range of temperature is between 20 Cº to 30 Cº. It requires minimum of 600 mm of annual rainfall (Qureshi & Afghan, 2005). There are three major stages for sugarcane growth sprouting and tillering , stalk growth and maturation (Begue, et al., 2010).

2.1.1 Germination and Establishment Phase

This phase starts from planting and lasts till germination of buds. Germination of buds starts from 7-10 days and lasts upto 30-35 days. It is affected by internal and external factors.

External factors include soil temperature, aeration and soil temperature. Sett moisture, Sett nutrient status and bud health are the internal factors.

2.1.2 Tillering Phase

Tillering is a physiological process of repeated underground branching from compact nodal joints of the primary shoot. It starts from 40 days and lasts upto 120 days.

2.1.3 Growth Phase

It starts from 120 days and lasts upto 270 days. It is the phase in which most of the cane formation and yield build up takes place.

2.2 Application of Remote Sensing in specific crop detection

All over the world cropped areas are estimated and crop production patterns are monitored to manage and estimate agricultural productions and these are critical for accurate information for policy makers (Maguranyanga & Murwira, 2014). Due to the advancement in remote sensing and image processing, now it is convenient to map large areas in an economical and fast way. Though remote sensing can successfully be used for mapping of crop and noncrop areas (Liu et al., 2005; Loveland et al., 2000; Xiao et al., 2005) , but it has rarely been used to map and estimate specific crop areas, hence they are the current focus of the researchers. Specific crop statistics are important for food security and crop marketing decisions, thus, it is critical to develop remote sensing approaches that can estimate the crop area and yield for a particular crop (Misra, Kumar, Patel, & Zurita-Milla, 2014).One of the first approach to derive specific crop statistics and map different crops on the basis of spectral characteristics involved single remotely sensed images taken at specific time of growing season particularly from earliest

Landsat satellite (Badhwar, 1984; Gusso & Ducati, 2012; Rembold & Maselli, 2006). In recent years development of finer spatial resolution has increased spatio-temporal domain based methods of mapping specific crops (Chang, Hansen, Pittman, Carroll, & DiMiceli, 2007). Time series data of specific crops was studied in Kansas USA and it was concluded that moderate resolution imaging spectroradiometer (MODIS) 250 normalised difference vegetation index (NDVI) had sufficient spatial and temporal resolution for major crop identification and as per the results spatial and temporal extents are critical for specific crop mapping. (Wardlow, Egbert, & Kastens, 2007). Recently MODIS NDVI temporal images were successfully used to map specific crops in Zimbabwe (Sibanda & Murwira, 2012).Results showed that spatio-temporal domain is critical for mapping specific crops.

2.3 Remote Sensing of Sugarcane

The maturation of sugarcane occurs when soil water content is low, temperature is decreasing. The crop is harvested when it is sufficiently matured and ripened. Sugarcane develop full Leaf Area Index (LAI) after about six to eight months but it can be affected by the type and health of the crop. The sunlight is intercepted by the top six leaves of the canopy. The number of green leaves on the stalk varies from six to twelve. Sugarcane has extraordinarily higher rates of photosynthesis (Rahman, Islam, & Rahman, 2004). The higher rates of photosynthesis and the LAI can be exploited through remote sensing and successfully be used to identify and map sugarcane crop. Ratio images are often useful in discriminating the differences of spectral reflectance by objects on ground. NDVI (Normalized Difference Vegetation Index) can be used to identify and estimate the sugarcane area and condition assessment (Rahman, et al., 2004)

2.2.1 Vegetation Indices

Vegetation Indices are the algorithms which can be used to concentrate complex and multiple information in a single band correlating with the physical characteristics of vegetation (Tucker 1979) .These indices are well documented and based on exclusive spectral properties of healthy and green vegetation . In the visible portion of electromagnetic spectrum (400-700 nm) absorption is predominant and reflectance is lower. In the visible portion there are two bands in which absorption occurs one is blue (450 nm) and other is red (670 nm) and reflectance peak occurs in green band (550 nm) of visible spectrum (Figure 1.1). This is due to the absorption of two main pigments chlorophyll a and b, which are 65% of total pigments. Due to reflectance peak in green portion chlorophyll is called green pigment and leaves appear to be green in colour. Similarly other pigments have peculiar characteristics and affect the physical properties of plants. One example of such pigment is carotene which has strong absorption in 350-500 nm and it is also responsible for colour of some fruits and flowers. There is more reflectance in the near infrared region (700-1300 nm) this reflectance depends on the leaf structure and thickness of mesophyll. An ideal vegetation index must be representation of plant canopy and not the soil in background. Most of the vegetation indices use the red band in which absorption occurs and the near infrared band in which reflectance occurs and it also contains 90% information about plant canopy.

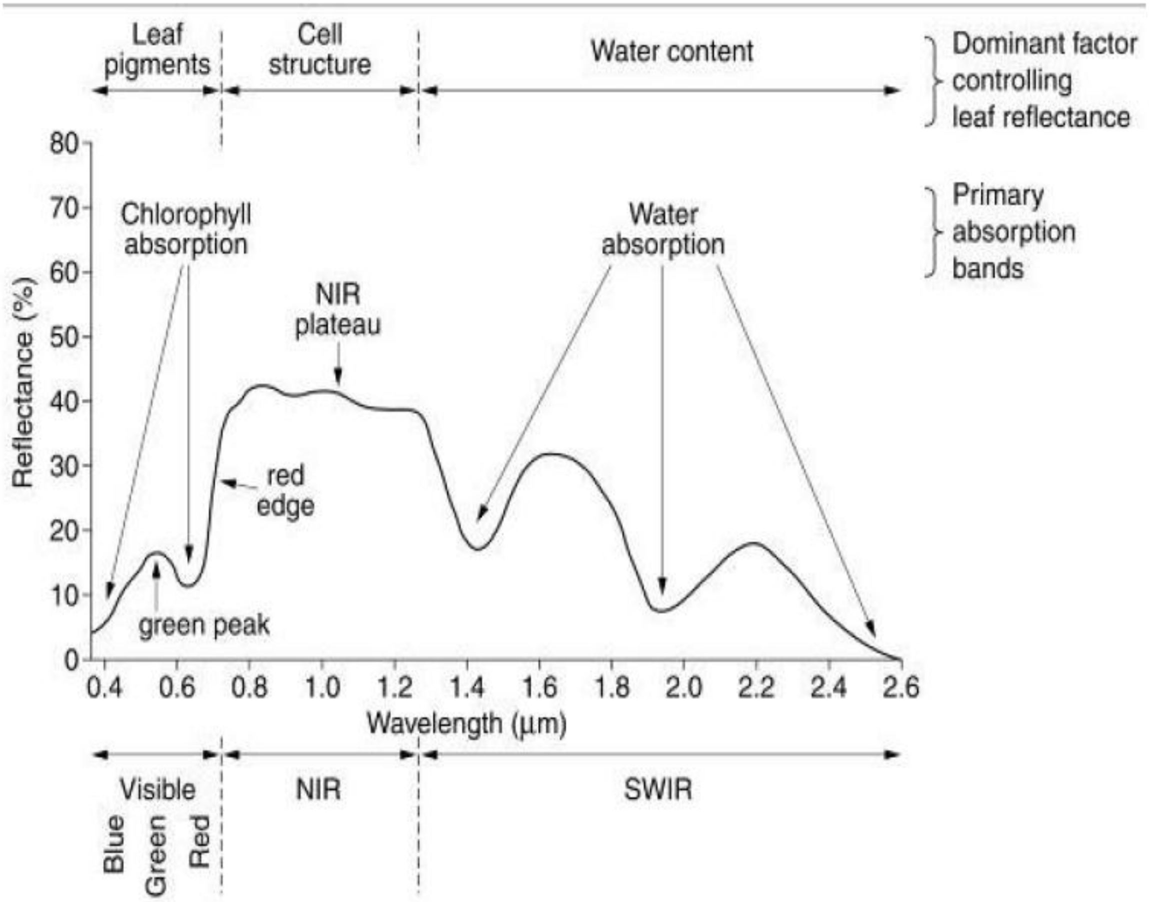


Figure 2.1. Typical spectral response of green vegetation

2.2.2 Normalised Difference Vegetation Index (NDVI)

NDVI is traditionally used by the researchers and it is representative of various vegetation indices (Rouse, Haas, Deering, & Sehell, 1974). It is the ratio of difference between the reflectance in red and near infrared to the sum of reflectance in red and near infrared bands. It is computed as

$$\frac{NIR - VIS}{NIR + VIS} \qquad (1)$$

Where

NIR= reflectance in near infrared region

VIS= reflectance in visible region

Theoretically NDVI varies from -1 to +1 but in actual it ranges between -1 and 0.7. Clouds, water and ice have negative values of NDVI whereas higher values of NDVI indicates green vegetation. Soils have a near-infrared spectral reflectance larger than the red, and thus they have small positive NDVI values (say 0.1 to 0.2). NDVI has been widely used in literature to extent the vegetation cover and crop condition. NDVI value were used for feature identification, mapping and crop condition was also evaluated (Rahman, et al., 2004).

2.2.3 Use of remote sensing for identification of sugarcane

SPOT 4 and SPOT 5 data was used to infer NDVI images and variation in NDVI values were linked to crop variables like LAI and leaf colour. It was found that variation in NDVI are a function of interaction between sugarcane crop calendar and crop phenology (Begue, et al., 2010). Sugarcane varieties can successfully be identified and discriminated using six different spectral indices NDVI, GVI (Green Vegetation index), SAVI (Soil Adjusted Vegetation Index), RVI (Ratio Vegetation Index), Ratio and GNVI created from LANDSAT 7 images (Fortes & Demattê, 2006). In Brazil sugarcane yield was forecasted using vegetation index inferred from Landsat and ASTER images, principal component analysis of these indices and historical yield data. The technique included following steps (a) Enhancement of spectral responses of vegetation (b) Reduction of spectral response to vegetation indices and principal component analysis (c) Image DNs and historical yield data were used to know the yield in tons per hectare (Almeida, De Souza Filho, & Rossetto, 2006) . Landsat TM data was tested for identification and classification of sugarcane areas in 46 farms of district Eston, South Africa. The estimates were within 5 % of what recorded by growers (Narciso & Schmidt, 1999).SPOT and Landsat imageries were used to map and calculate sugarcane areas in Australia (Markley, Raines, & Crossley, 2003).Landsat and ASTER Data was used for classification of sugarcane fields and a spectral signature library was developed for identification and analysis of sugarcane (Vinod & Kamal).In Sao Paulo state , three Landsat images of Landsat 7 ETM+ were used to extract spectral variables like NDVI , reflectance in Band 4 and GVI. The simple linear regression was performed among sugarcane yield and the three spectral variables. The temporal differences were substantial for GVI index and reflectance of band 4. However, they were not substantial for the NDVI index, which is indicative of a less sensitivity of this index to detect multi-temporal differences in sugarcane spectral response during its lifecycle (BenvenutiA & WeillB, 2010).

2.3 Social and economic factors affecting crops

In agricultural countries like Pakistan any external or internal shock to agriculture, affects the lives of people (Bashir, Mehmood, & Hassan, 2010). Factors affecting sugarcane crop sowing in Pakistan were determined by collecting the data from the farmers across the country in three provinces Punjab, Sindh, and Khyber Pakhtunkhwa. It was concluded that costs of inputs like land preparation, seeds, urea, Farm yard manure (FYM), weeding and cost of irrigation are higher than the returns earned by the growers (Nazir, Jariko, & Junejo, 2013). In a study carried out in India cost of cultivation from 1976 till 2006 for six major crops including Paddy, Wheat, Gram, Groundnut, Sugarcane and Cotton were analysed. It was found that whenever cost of cultivation increase faster than the returns and output, the farmers may not be inclined to adopt required inputs for cultivation (Narayanmoorthy, 2013). In India over 2 lakhs farmers have committed suicides from 1990-91 till 2009-10 (Sainath, 2011). Some studies have reported that the imperfect market conditions, decline in productivity of crops and lack of institutional credit are the major causes for the farmers to commit suicide (Mishra, 2012). Profitability of sugarcane crops in district Faisalabad, Pakistan was assessed and it was found that average yield per acre for sugarcane in Faisalabad was quiet low as compared to other districts and cost of production per acre is high. Factors like preparatory tillage, seeding, water availability, application of fertilizers, time and type of harvesting affect the production of sugarcane as well (Naeem, Bashir, Hussain, & Abbas, 2007). In India a study was carried out to analyse the impacts of key policies of government including subsidized farm level prices of seeds, fertilizers energy and irrigation water. The results showed that farmers responded belligerently to the subsidies in areas where their net returns increased significantly by switching from outdated to new varieties and by spreading their cropping patterns to two or three crops per year on the same land (Wichelns, 2004). In Pakistan requirement of agricultural credit to farmers was studied and it was revealed that use of better mix of inputs by farmers require funding but due to lack of funds at the disposal of farmers, many small farmers are not in position of acquiring key inputs such as improved seeds, fertilizers and advanced technology. Thus to meet the requirements to increase the production, agricultural credit is vital (Iqbal, Ahmad, Abbas, & Mustafa, 2003).

The objective of this dissertation is to identify and map sugarcane fields using remotely sensed data, analyse the sowing trend of sugarcane from year 2008 till 2014 in the study area and find out socio-economic causes of trend adopted by the farmers.

Chapter 3

MATERIAL AND METHODS

The current study aims to understand the sowing trend of sugarcane adopted by farmers and its causes. Remote sensing technique, with an equitable grade of accuracy encompassing period of past seven years from 2008 to 2014, was used. Landsat data was used to achieve the objective.

3.1 Study Area

The Study area consists of second largest province of Pakistan, Punjab. It extends from latitude 30.7900° N and longitude 76.7800°E. Its total area is 79,284 sq miles and it has 36 districts. Climatically Punjab has three major seasons. First is the hot weather it extends from April to June where temperature goes upto 50 Cº in some areas. Second, is the rainy season which extends from July to September. Third is the cooler and mild weather which exists from October till March. During this period temperature goes down to -10 Cº. The Punjab province has about 29% of the total reported, 57% of the total cultivated and 69% of the total cropped area of Pakistan. Land utilisation statistics are shown in Table 3.1 It contributes a major share in the agricultural economy of the country by providing about 83% of cotton, 80% of wheat, 97% fine aromatic rice, 63% of sugarcane and 51% of maize to the national food production. Among fruits, mango accounts for 66%, citrus more than 95%, guava 82% and dates 34% of total national production of these fruits.

There are mainly two principal cropping season in Punjab , Pakistan Rabi and Kharif crops

(Bakhsh, Hassan, & Maqbool, 2005). Rabi crops are the one which are sown in winter and harvested in spring it includes wheat, mustard, barely and peas. Kharif crops are the one which are sown in June, July and harvested in October. It includes Rice, Cotton, Maize and Millet. Sugarcane is the annual crop usually sown in February, March and harvested in January, February next year (Ahmed & Schmitz, 2011). Sugar Industry is the second largest industry of Pakistan. Punjab produces almost 65% of sugarcane produced in Pakistan (SPBP, 2012). There are a total of 85 sugar mills in Pakistan which has the estimated capacity of 72 million tons. Out of 85 sugar mills 45 are in Punjab (Khan, 2013). The study area is shown in Figure 3.1.

Table 3.1. Land utilization statistics Punjab (*Source: Agricultural Statistics of Pakistan 2011-12*)

Area	**Pakistan** *(Area in million hectares)*	**Punjab** *(Area in million hectares)*
Geographical Area	79.61	20.63
Forest area	4.27	0.49
Not available for cultivation	23.25	2.91
Culturable waste	8.20	1.60
Cultivated area	22.04	12.51
Total reported area	57.76	17.51
Current fellow	7.05	2.06
Net area sown	14.99	10.45
Area sown more than once	7.52	6.16
Total cropped area	22.51	16.61

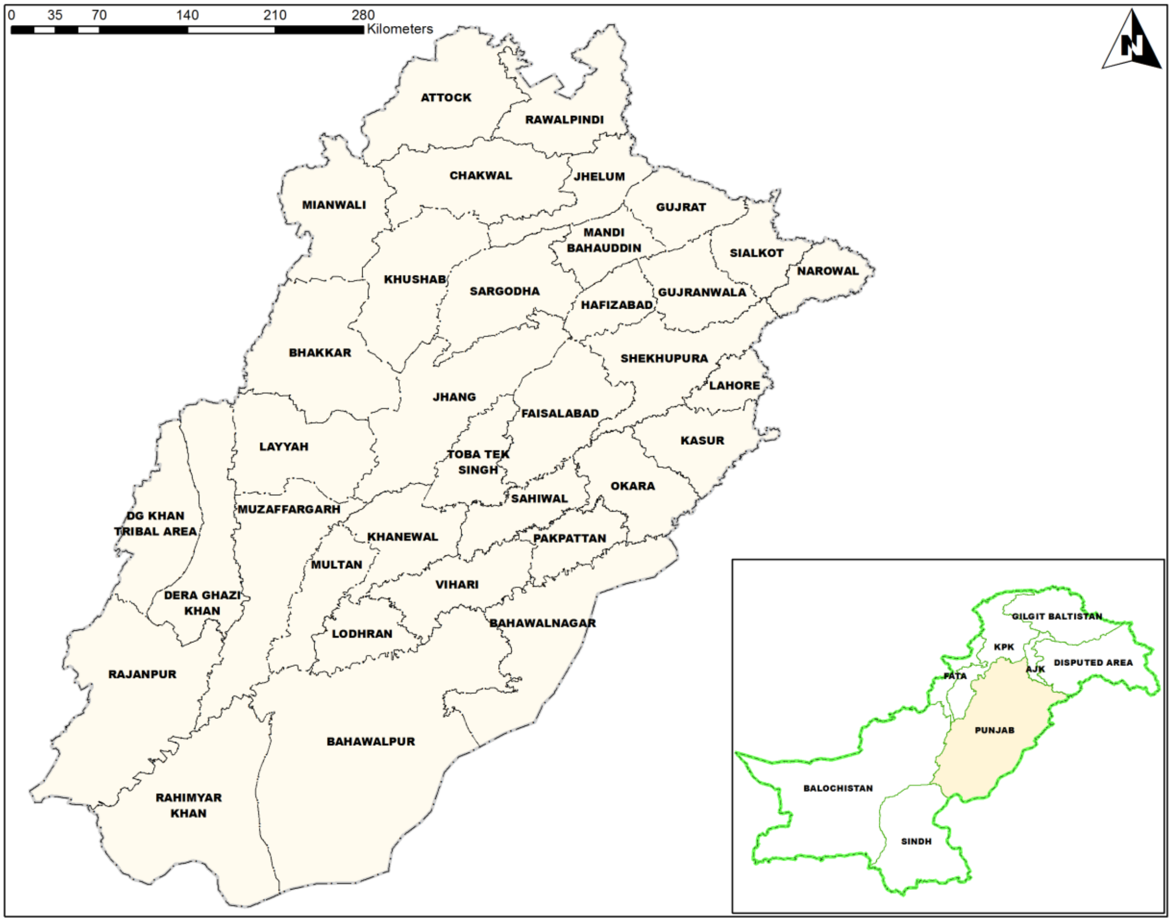


Figure 3.1. The study area (Punjab Province of Pakistan)

3.2 Data availability and requirement

The data required for the different phases of research was defined after conducting literature review. Table 3.2 shows the details

Table 3.2. Data sets used

S/No	Data Required	Source
1	Ground truth Data	Will be collected in field
2	LANDSAT Imagaries	Glovis/ USGS
3	Sugarcane area	Crop Reporting Service (CRS) department of the Government of Punjab
4	Location and Capacity of Sugar mills	Pakistan Sugar Mills Association (PSMA)
5	Support price of Sugarcane	Pakistan Bureau of Statistics (PBS)

3.2.1 Satellite Data

Examining sowing trend for sugarcane and change in the trend over a long period of time requires satellite data every year at the appropriate time. Images of Landsat-5 TM and Landsat-7 ETM+ and Landsat-8 encompassing the period of seven years (2008-2014). Images of whole Punjab province were acquired for 2008-2014. Landsat covers Punjab province in 13 tiles and Landsat-5 TM, Landsat-7 and Landsat-8 ETM+ WRS-2 descending were acquired for each year, as shown in Fig 3.2 (b). Landsat images have been used extensively to study crops on the basis of NDVI (Abdel Rahman & Ahmed, 2008).

Bands of Landsat 5, Landsat 7 and Landsat 8 satellites and their data are shown in table 3.3, table 3.4 and table 3.5.

Table 3.3. Landsat 5 bands

Landsat 5 Thematic Mapper (TM) Launched March 1, 1984	**Bands**	**Wavelength (micrometers)**	**Resolution (meters)**
	Band 1 - Blue	0.45 - 0.52	30
	Band 2 - Green	0.52 - 0.6	30
	Band 3 - Red	0.63 - 0.69	30
	Band 4 -NIR	0.76 - 0.9	30
	Band 5 - NIR	1.55 – 1.75	30
	Band 6 - TIRS	10.4 – 12.5	120
	Band 7 – Mid IR	2.08 - 2.30	30

Table 3.4. Landsat 7 bands

Landsat 7 Thematic Mapper (ETM+) Launched April 15, 1999	**Bands**	**Wavelength (micrometers)**	**Resolution (meters)**
	Band 1 - Blue	0.45 - 0.52	30
	Band 2 - Green	0.52 - 0.6	30
	Band 3 - Red	0.63 - 0.69	30
	Band 4 -NIR	0.76 - 0.9	30
	Band 5 - NIR	1.55 – 1.75	30
	Band 6 - TIRS	10.4 – 12.5	60
	Band 7 – Mid IR	2.08 - 2.30	30

Table 3.5. Landsat 8 bands

Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) Launched February 11, 2013	**Bands**	**Wavelength (micrometers)**	**Resolution (meters)**
	Band 1 - Coastal aerosol	0.43 - 0.45	30
	Band 2 - Blue	0.45 - 0.51	30
	Band 3 - Green	0.53 - 0.59	30
	Band 4 - Red	0.64 - 0.67	30
	Band 5 - Near Infrared (NIR)	0.85 - 0.88	30
	Band 6 - SWIR 1	1.57 - 1.65	30
	Band 7 - SWIR 2	2.11 - 2.29	30
	Band 8 - Panchromatic	0.50 - 0.68	15
	Band 9 - Cirrus	1.36 - 1.38	30
	Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	100 * (30)

3.2.2 Statistical Data

Statistical agricultural census data released by the Crop Reporting Service (CRS) department of the Government of Punjab, Pakistan, was used in this study. It includes the sown area and estimated yield for sugarcane and all other crops grown in Punjab. Every year, CRS acquires about 5% of sample data from randomly selected crops, through thousands of crop reporters. Field data collected by reporters is statistically evaluated by experts at CRS and crop areas, yields and production estimates are calculated (CRS, 2012).

CRS produces three official estimates for each crop at different stages of crop growth. The final estimates of sown area corresponding to different crops are based on surveys carried out by government land tenure officials from the Pakistan Revenue Department for tax purposes (CRS, 2012). Statistical data regarding gains and returns earned by growers of different crops were collected in the field through questionnaires, following the method of (Ahmad, Javed, Nazam, & Nazim, 2014).

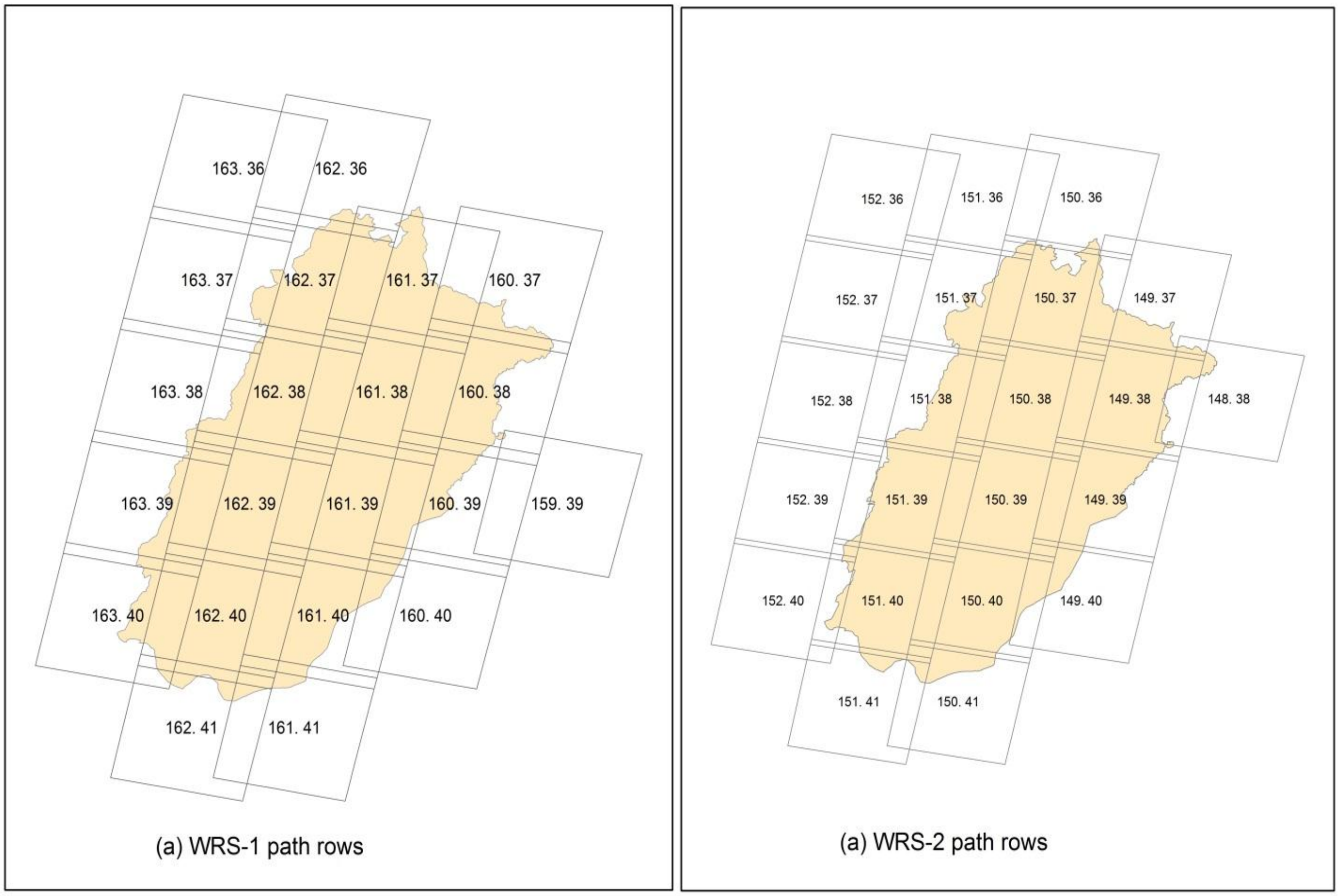
3.3 Software

Software used in this research are, Leica Geosystem's Erdas Imagine ™, ESRI's ArcMAP ™ and ENVI.

3.4 Analytical Framework

The methodology adopted for the research is shown in Fig 3.3. Methodology followed was sub divided into two phases

1. Identification and Mapping of sugarcane fields through remotely sensed data;
2. Socio- economic causes of the sowing trend for sugarcane crop;



The Worldwide Reference System (WRS) is a global notation used in cataloging Landsat data. Landsat 8 and Landsat 7 follow the WRS-2, as did Landsat 5 and Landsat 4. Landsat 1, Landsat 2, and Landsat 3 followed WRS-1. Ascending mode means night time captured data. and descending mode means day time captured data

Figure 3.1. (a) WRS-1path row (b) WRS-2 path row

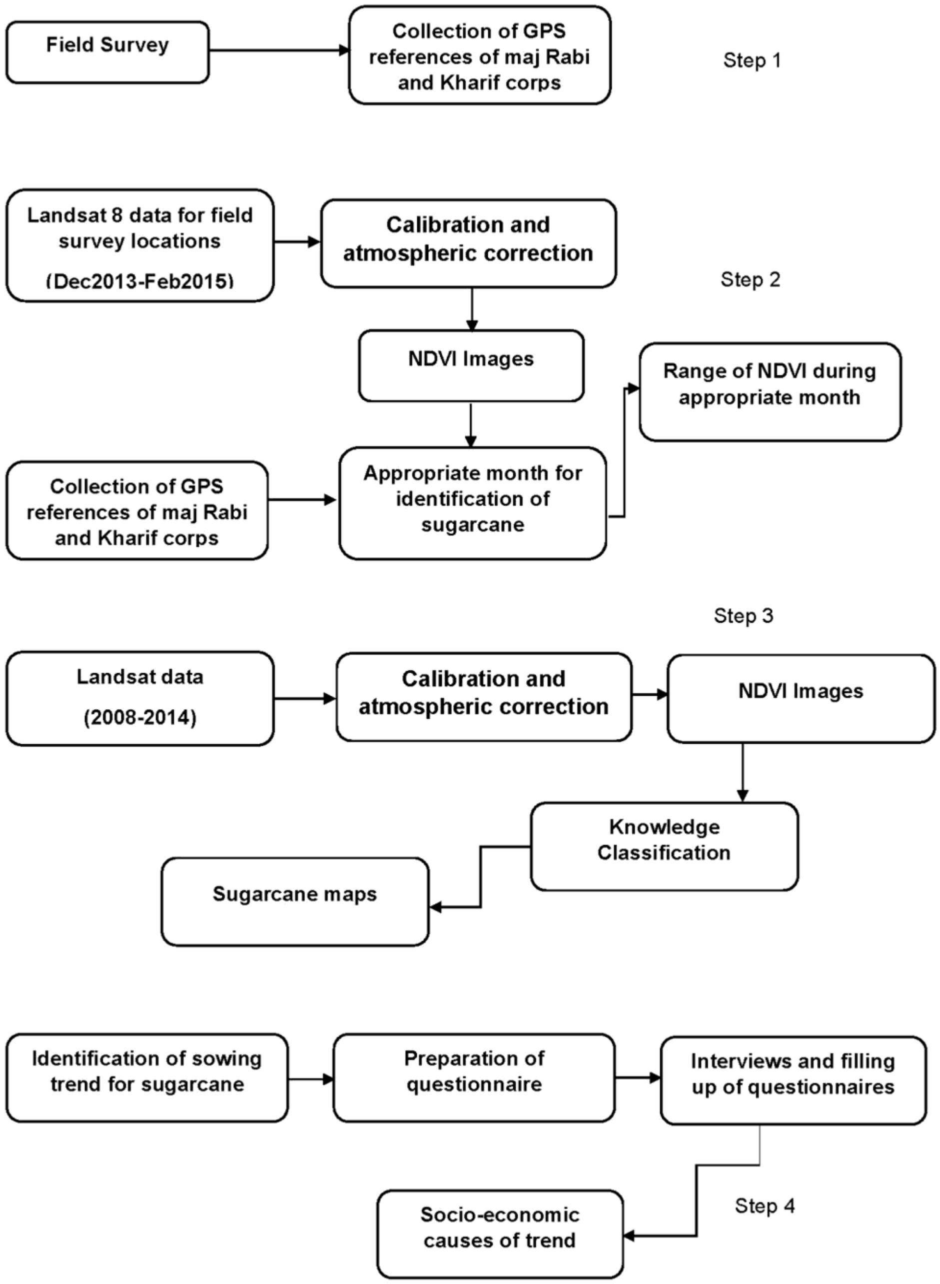


Figure 3.3. Flow diagram showing sugarcane identification, mapping and analysis of sowing trend

3.4.1 Identification and mapping of sugarcane fields

Field Survey was carried out in the area around Noon Sugar Mill in district Sargodha and area around Brother Sugar Mill in district Okara. Landsat 8 imageries of 2013-14 for the survey area were used to infer the NDVI images. There were two questions to be answered

(1) Finding the appropriate month for the identification and mapping of sugarcane Crop.

(2) Finding the range of NDVI for sugarcane crop in month Identified.

3.4.1.1 Field Survey

Field survey was carried out in the area around Noon sugar mill and Brother Sugar Mill was carried out. The GPS references of different crop fields were obtained through GPS to exactly know the different crops locations. These included fields of Kharif crops like Wheat, Mustard, Rabi crops like Rice, Bajra, Cotton, annual crop sugarcane, grass and a garden of fruiter (local variety of oranges). Locations for field survey are shown in Figure 3.4

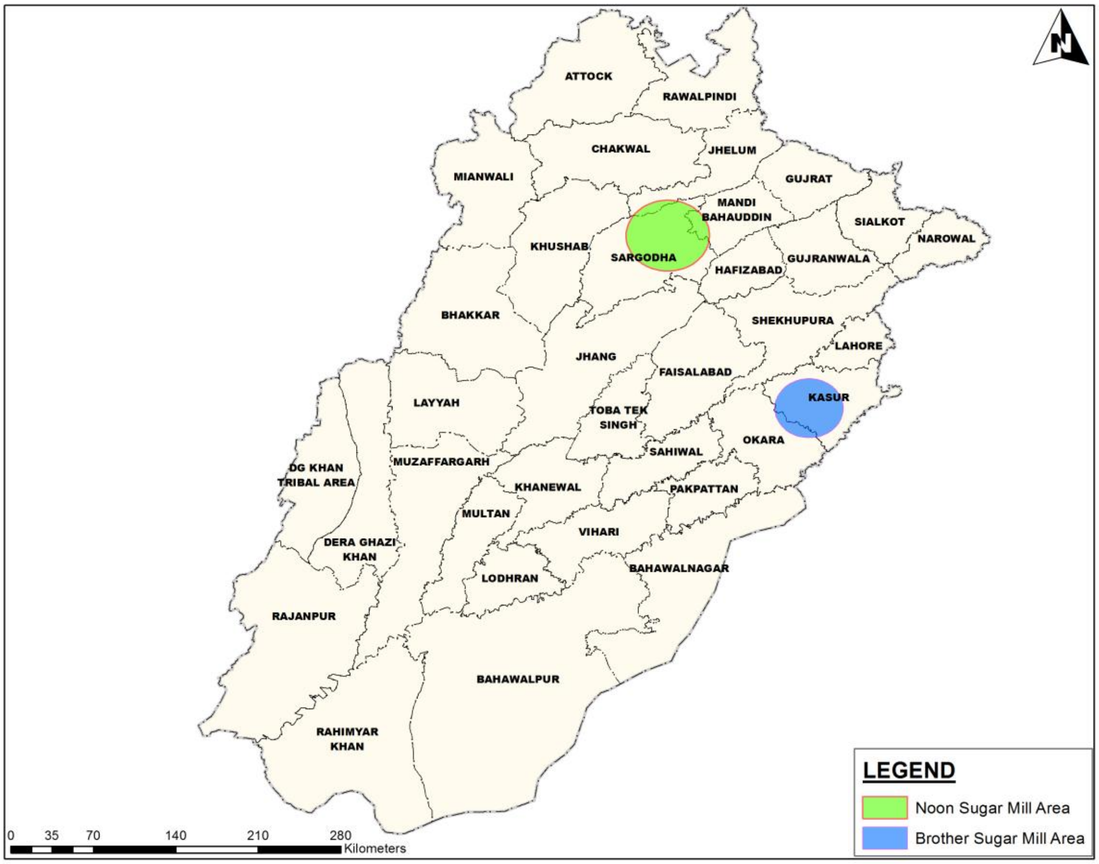


Figure 3.4. Locations for field Survey

3.4.1.2 Finding appropriate month for identification of sugarcane

To find the appropriate month it was necessary to know the NDVI values for different crops for the whole crop cycle including both Rabi and Kharif crops. Landsat 8 images of both areas of field survey from December 2013 till February 2015 were used.

3.4.1.2a Data acquisition and assimilation

Landsat-8 OLI data for field survey locations, from December 2013 till February 2015 were downloaded from USGS GLOVIS and were pre-processed. Figure 3.5 shows flow chart of phase 1.

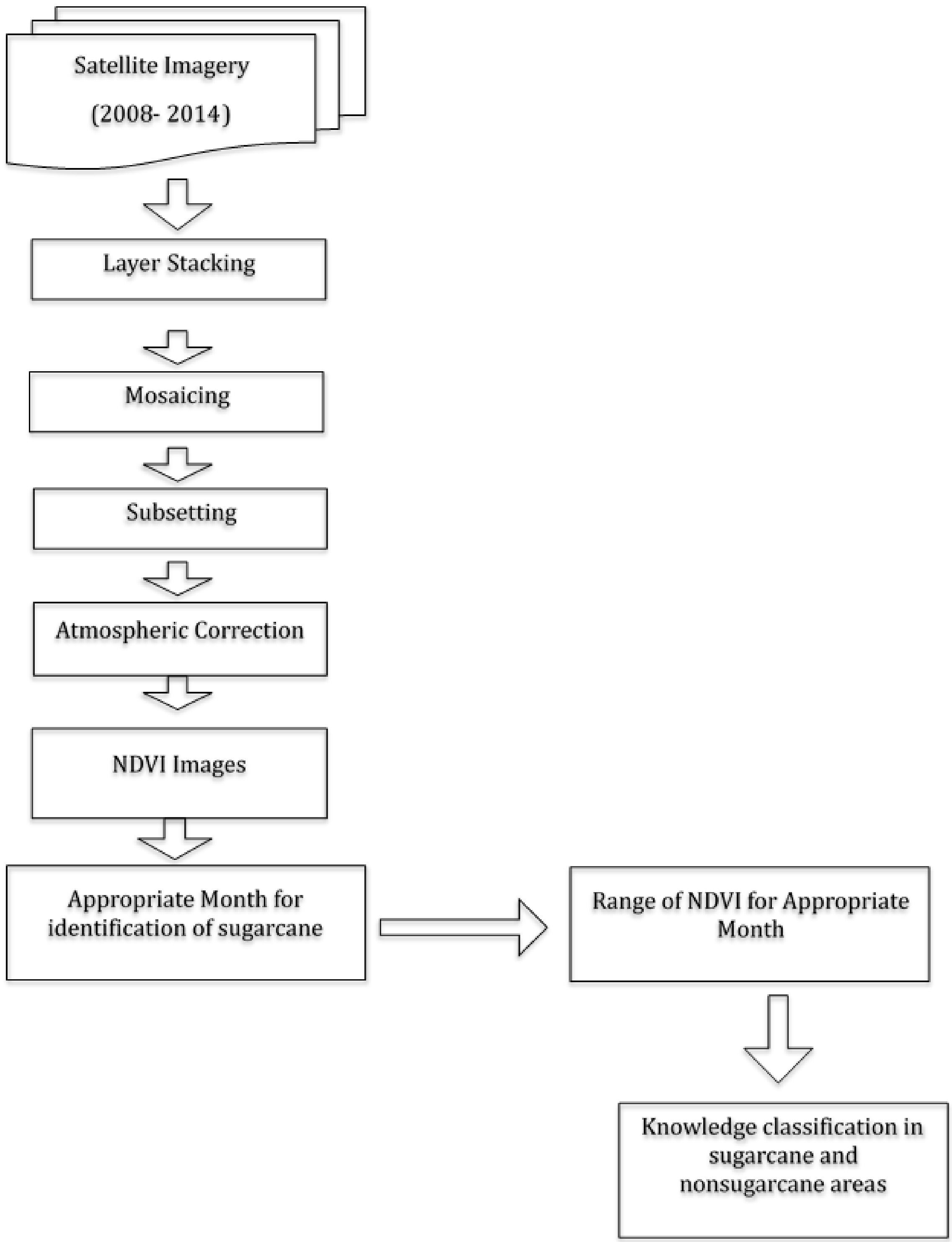


Figure 3.5. Flow chart Phase 1

3.4.1.2b Layer stacking

Satellite images were acquired and stacked. “Layer Stacking” was used to produce a multi-band layer from a number of georeferenced images. In this procedure the input bands are re-projected and resampled to a mutual user-selected pixel size and projection. The data acquired was already rectified and projected in Universal Transverse Mercator (UTM) system.

3.4.1.2c Mosaic

As field survey locations near Noon sugar mill was covered by only one tile for each year and area around brother sugar mill was covered by two tiles. To cover definite area it was required to combine these satellite imageries into a single satellite photo for advance processing so both tiles of area around brother sugar mill for each year were mosaicked as single image.

3.4.1.2d Spatial subsetting

In spatial subsetting mosaicked image was clipped according to spatial extent of Noon and Brother sugar mill areas and further analysis were performed specifically on the subset area.

3.4.1.2e Atmospheric Correction

Solar radiation reflected from the earth’s surface travels through atmosphere before reaching satellite sensors. This interaction with the atmosphere modifies certain aspects of reflected radiations (D. G. Hadjimitsis et al., 2010). Atmospheric corrections are applied to determine true surface reflectance by removing atmospheric effects. Such corrections are specially important where temporal images are used for agricultural studies (D. G. Hadjimitsis, et al., 2010). The Darkest pixel (DP) method, considered the most effective method for applying atmospheric corrections, was used in this study. The working principle behind darkest pixel method is that most of the signals reaching satellite sensors from dark objects are due to atmospheric effects (D. Hadjimitsis, Clayton, & Retalis, 2003). In each tile, the darkest objects such as water bodies were selected. Initially, digital numbers were converted to radiance by using standard calibration values taken from metadata contained in header files following the methods of (Agapiou, Hadjimitsis, Papoutsa, Alexakis, & Papadavid, 2011; D. G. Hadjimitsis, et al., 2010). This was performed using eq 3.1

$$L_{sat} = [(Lmax_{\lambda} - Lmin_{\lambda})/Qcalmax] \times Qcal + Lmin_{\lambda} \qquad (3.1)$$

Where

L_{sat}: apparent spectral radiance at satellite sensor ($W \cdot m^{2} \cdot ster^{1} \cdot \mu m^{1}$),

$Lmax_{\lambda}$ and $Lmin_{\lambda}$: the calibration constants, ($W \cdot m^{2} \cdot ster^{1} \cdot \mu m^{1}$),

Qcalmax: the maximum quantized calibrated pixel value and

Qcal is the digital number of the image

The images were then calibrated and satellite radiance values were converted to satellite reflectance using solar zenith angle, sun-earth distance correction and solar irradiance at the top of the atmosphere using eq 3.2

$$\rho = (\pi \times L_{sat} \times d^{2})/ESUN_{\lambda} \times \cos\theta_{s} \qquad (3.2)$$

where:

ρ: spectral reflectance at the surface (%),

d: earth-sun distance in Aus,

$ESUN_{\lambda}$: solar spectral irradiance on a surface perpendicular to the sun's ray outside of the atmosphere

$(W \cdot m^{2} \cdot \mu m^{1})$ and

$Cos\theta_S$: cosine of solar zenith angle.

In the final step DP was applied, in which average reflectance value of dark objects, i.e. is the water body, was subtracted from each reflectance value in each spectral band

3.4.1.2f Calculation of NDVI

Normalized Difference Vegetation Index (NDVI) is the image digital processing technique that includes reflectance connections in the visible and NIR. NDVI method focuses image algebra and is defined as:

$$\frac{(NIR-Red)}{(NIR+Red)} \qquad \text{……………………..} \ (3.3)$$

NDVI images for all months were inferred from these images to know the NDVI values for all the crops. NDVI images for a few months are shown in Figure 3.6 Figure 3.7.

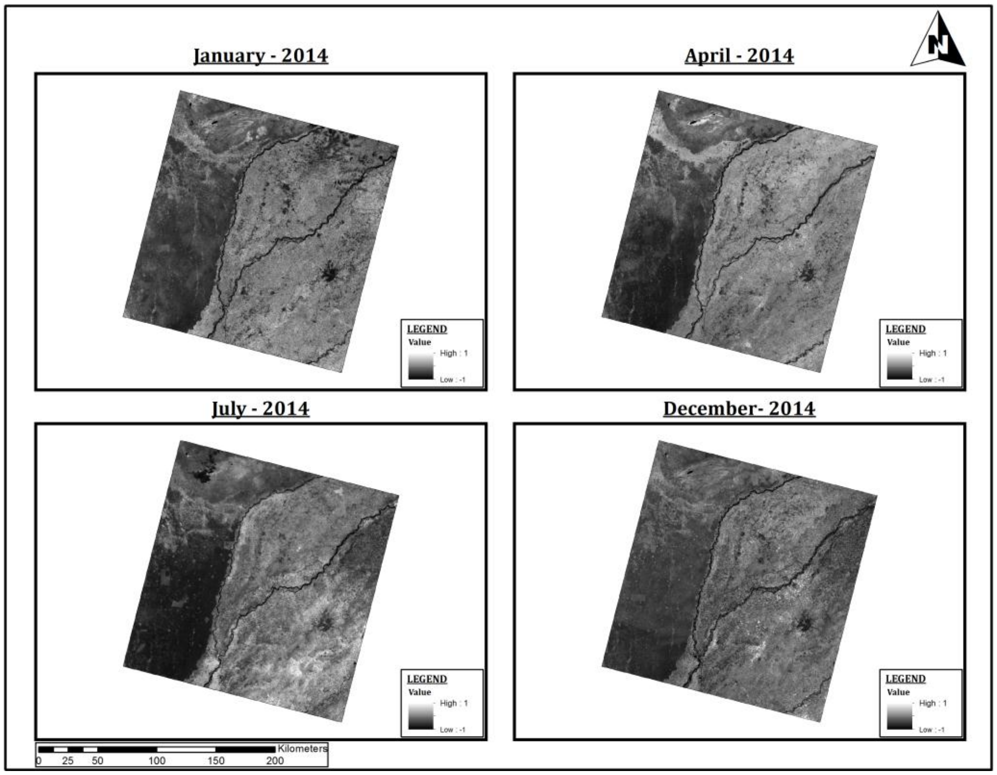


Figure 3.5. NDVI maps field survey locations (Noon Sugar mill)

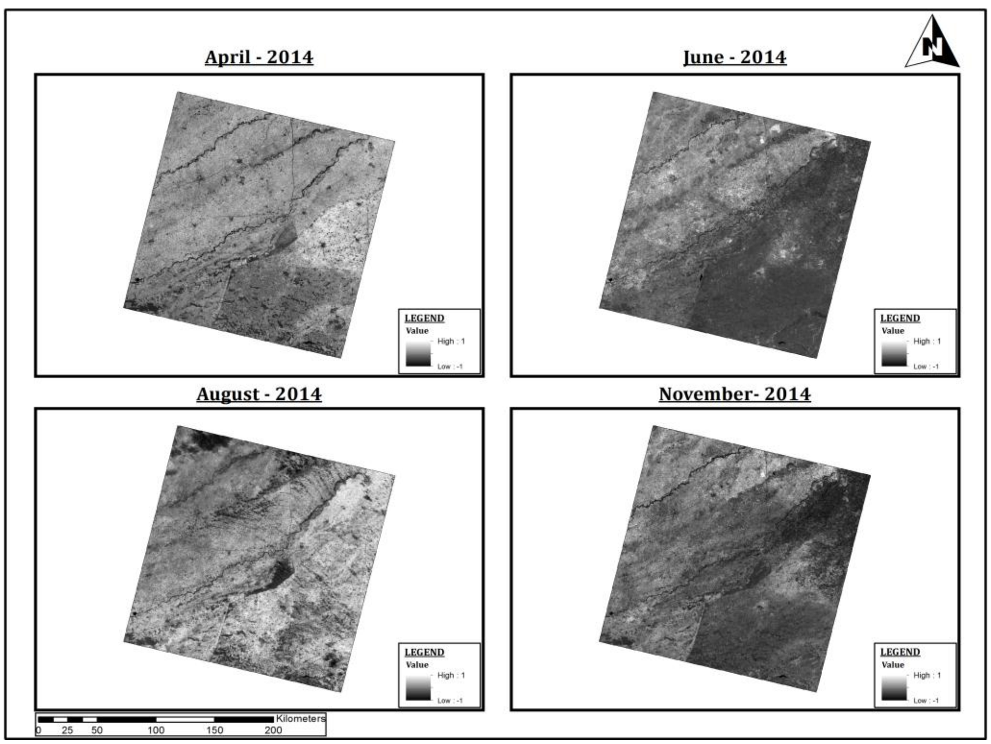


Figure 3.6. NDVI maps field survey locations (Brother Sugar mill)

3.4.1.3 Finding the appropriate month for identification of sugarcane

NDVI values for all the major Rabi and Kharif crops of the area were concluded from those NDVI images and are shown Table 3.6 and Table 3.7. For Noon sugar mill area the images for the months Mar 2014, May 2014, Aug 2014, Sep 2014, Nov 2014 and Jan 2015 could not be procured because of no cloud free remotely sensed data available for above mentioned months. For Brother sugar mill area the images for Jan 2014, Feb 2014, May 2014, July 2014, Sep 2014 and Jan 2015 could not be downloaded because no cloud free data was available for these months. Once the graphs were generated from above two tables (Figure 3.7 &3.8), it can be observed that during month of November and December NDVI values for all other crops are on the lower side whereas the NDVI values for sugarcane are on the higher side. We can conclude that November and December are the two months which are suitable for the identification and mapping of sugarcane.

Table 3.6. NDVI values all crops field survey locations (Noon Sugar mill area)

Date	Sugarcane	Wheat/Rice	Masturd/Bajra
3-Dec-13	0.19	0.09	0.128
4-Jan-14	0.098	0.105	0.162
5-Feb-14	0.12	0.253	0.233
10-Apr-14	0.144	0.266	0.341
13-Jun-14	0.19	0.128	0.113
15-Jul-14	0.244	0.145	0.259
3-Oct-14	0.324	0.296	0.162
6-Dec-14	0.263	0.062	0.196
8-Feb-15	0.19		

Table 3.7. NDVI for all crops field survey locations (Brother Sugar mill Area)

Date	Sugarcane	Wheat/Rice	Masturd/bajra	Sunflower
12-Dec-13	0.312	0.137	0.227	0.15
2-Mar-14	0.099	0.258	0.307	0.283
3-Apr-14	0.234	0.11	0.251	0.184
6-Jun-14	0.275	0.32	0.151	0.13
9-Aug-14	0.248	0.088	0.288	
12-Oct-14	0.287	0.135	0.231	
13-Nov-14	0.314	0.111	0.082	

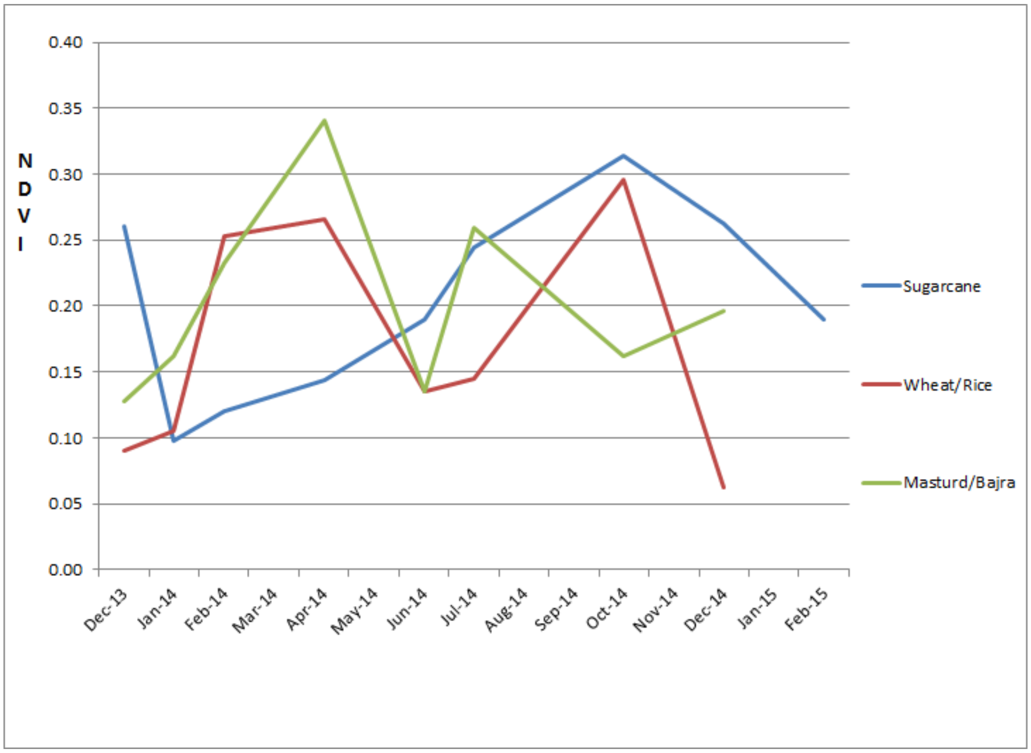


Figure 3.8. NDVI values for all crops (Noon sugar mill area)

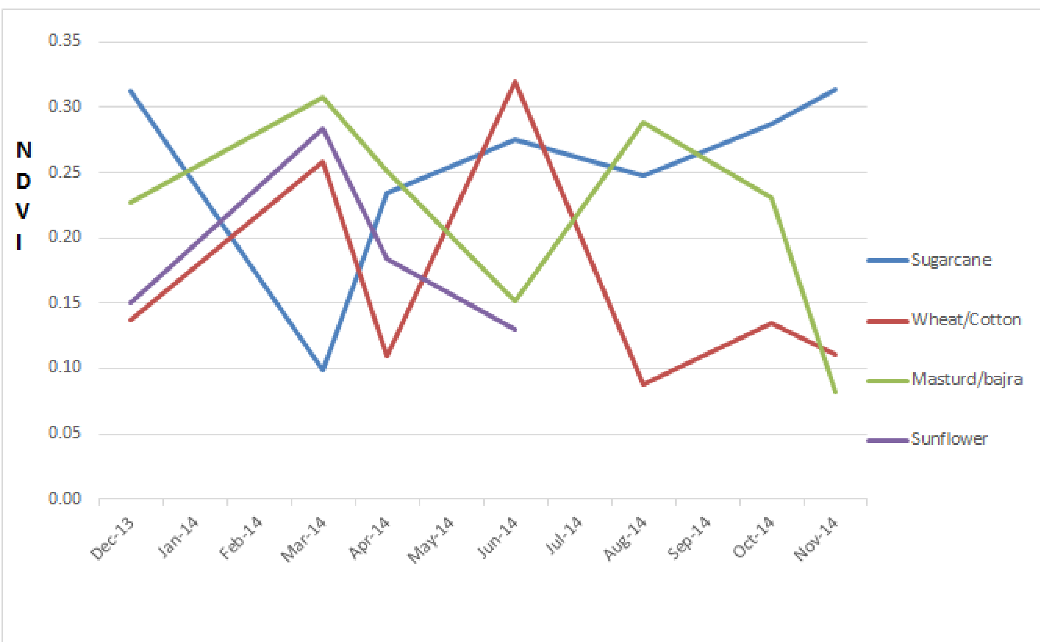


Figure 3.9. NDVI values for all crops (Brother Sugar mill area)

3.4.1.4 Finding the range of NDVI

After finding the appropriate month, the Landsat 8 imagery of field survey area for November and December 2014 were downloaded and NDVI images were created. NDVI values for sugarcane fields were obtained. The sugarcane fields were the same whose locations were obtained during field survey. NDVI range is shown in Table 3.7.

Table 3.8. Range of NDVI for all crops during month of Nov and Dec

Wheat/Rice	**Sugarcane**	**Mustard/Bajra**	**Misc.**
0.067	0.28	0.196	0.207 (Grass Open place)
0.165	0.31	0.103	0.22 (Grass)
0.062	0.263	0.195	0.221
0.052	0.25	0.165	0.23 (Fruiter garden)
0.067	0.251	0.196	0.407 (Fodder)
0.058	0.27	0.132	0.207
	0.32		
	0.282		
	0.278		
	0.24		
	0.34		

It was observed that NDVI values for sugarcane crop during month of November and December vary in between 0.24- 0.34 as concluded by Rahman, et al. (2004).

3.4.2 LULC classification

Landsat 7 & 8 imagery of the months November and December for the years 2008 to 2014 for 21 districts of Punjab was acquired from the U.S Geological Survey (USGS). NDVI images were then created from this Landsat data. These NDVI images were classified into four major classes; water, built up area, barren land and vegetation (Table 3.9). Major classes, these classes include water, vegetation, built up areas/ roads and barren land (figure 3.10 to figure 3.12). During the process of classifying Landsat images, there was some confusion between the identification of built up areas and barren land. However, this study focused on vegetation which was the only class clearly identified and classified without any confusion with other classes. The vegetation class was further classified into sugarcane and non-sugarcane areas using the range of NDVI values during months of November and December (Figure 3.13). Maps for sugarcane fields for 21 districts were subsequently generated (Figure 3.14, 3.15 &3.16).

Table 3.9. Range of NDVI for all crops during month of Nov and Dec

S/No	Class	NDVI values	Remarks
1	Water	< 0	
2	Built up area	0.0 to 0.05	
3	Barren land	0.05 to 0.15	
4	Vegetation	0.16 to 0.7	

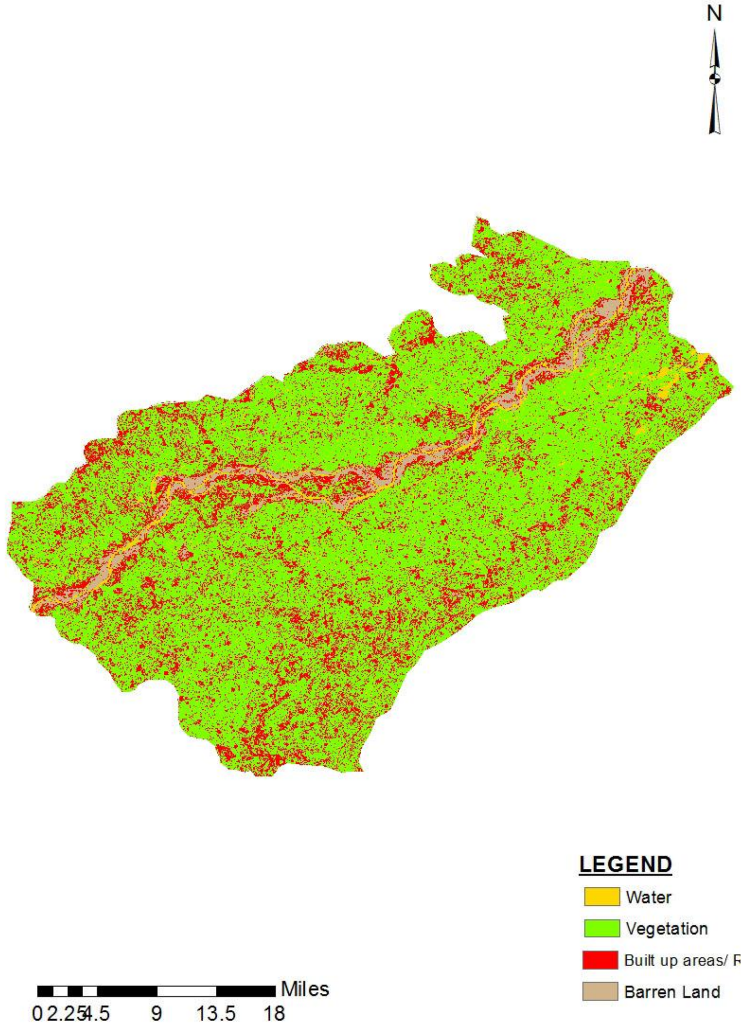


Figure 3.10. Classified map of district Chaniot 2014

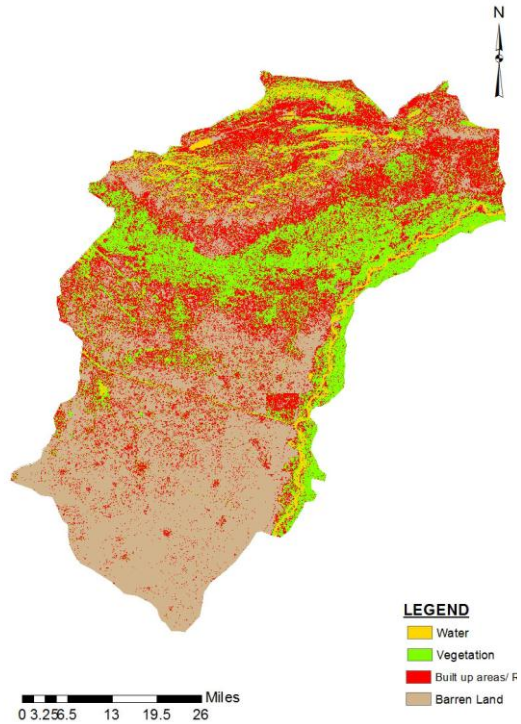


Figure 3.11. Classified map of district Khushab 2014

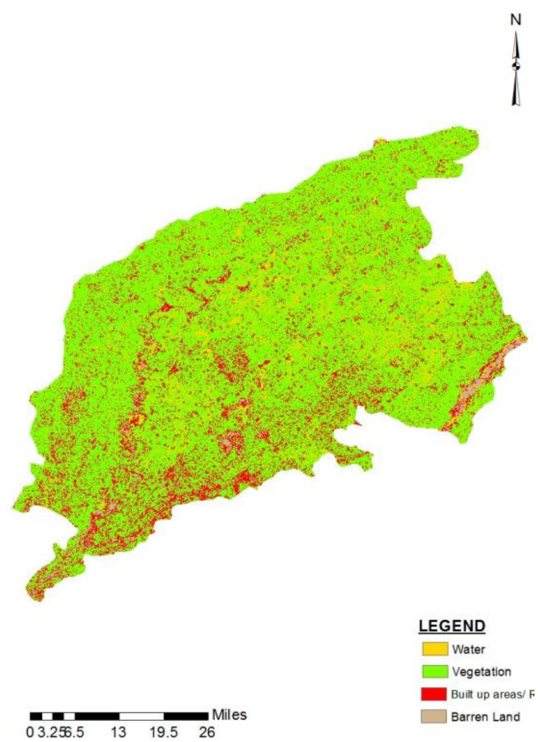


Figure 3.12. Classified map Sargodha district 2014

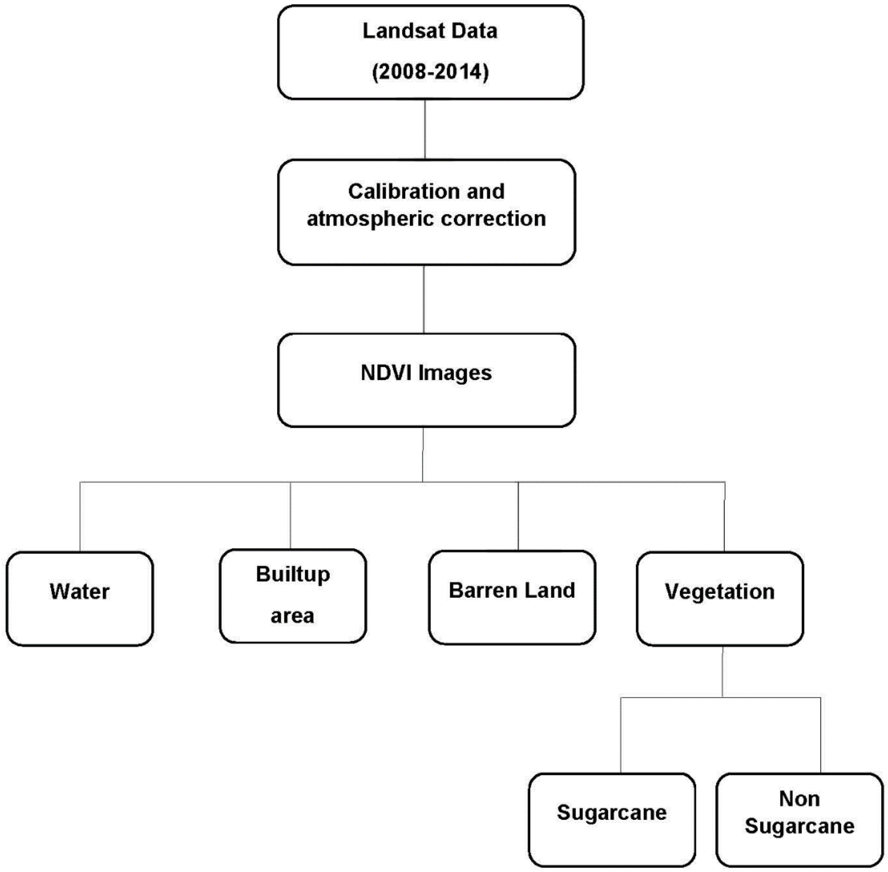


Figure 3.13. Knowledge based classification scheme for identification of sugarcane fields

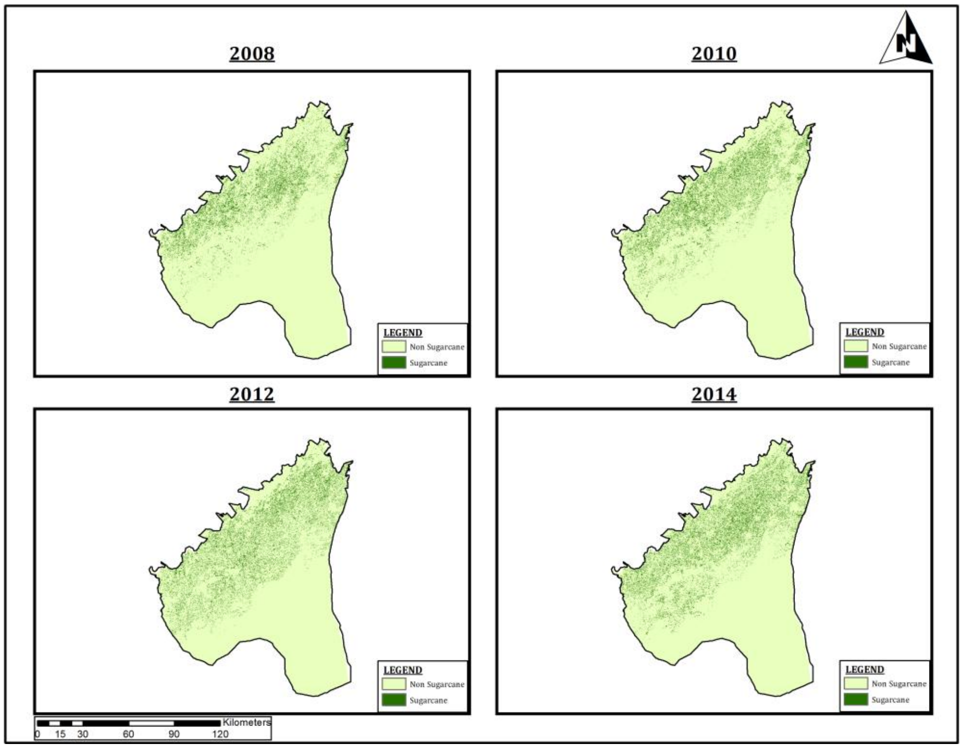


Figure 3.14: Sugarcane maps Rahim Yar Khan district

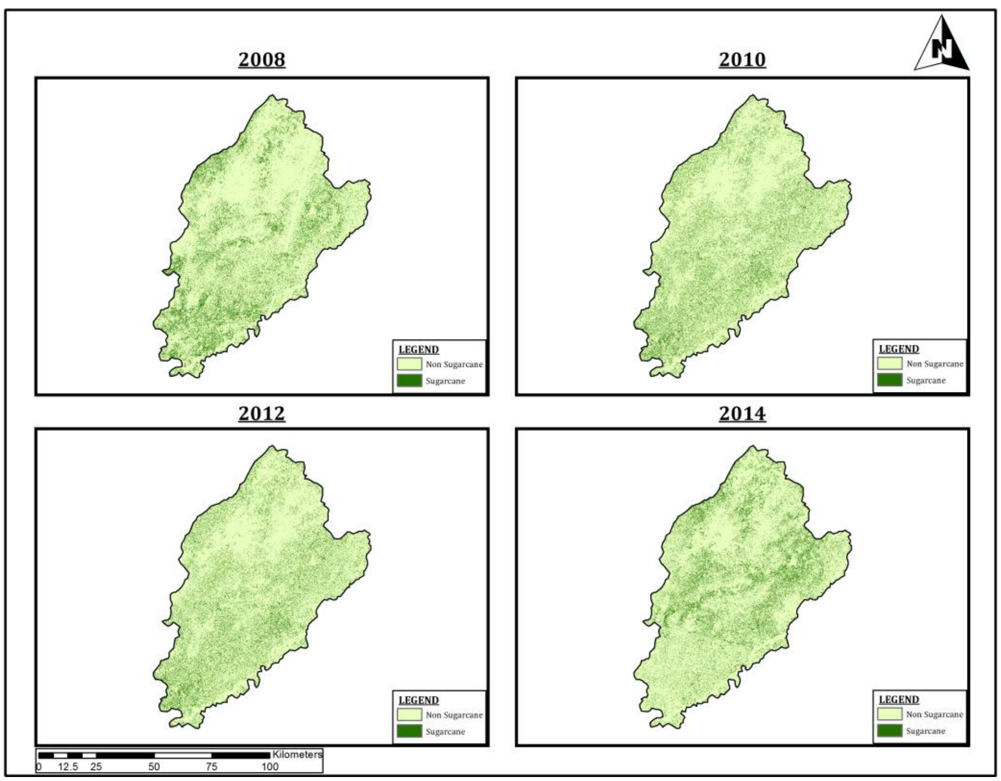


Figure 3.15: Sugarcane maps Faisalabad District

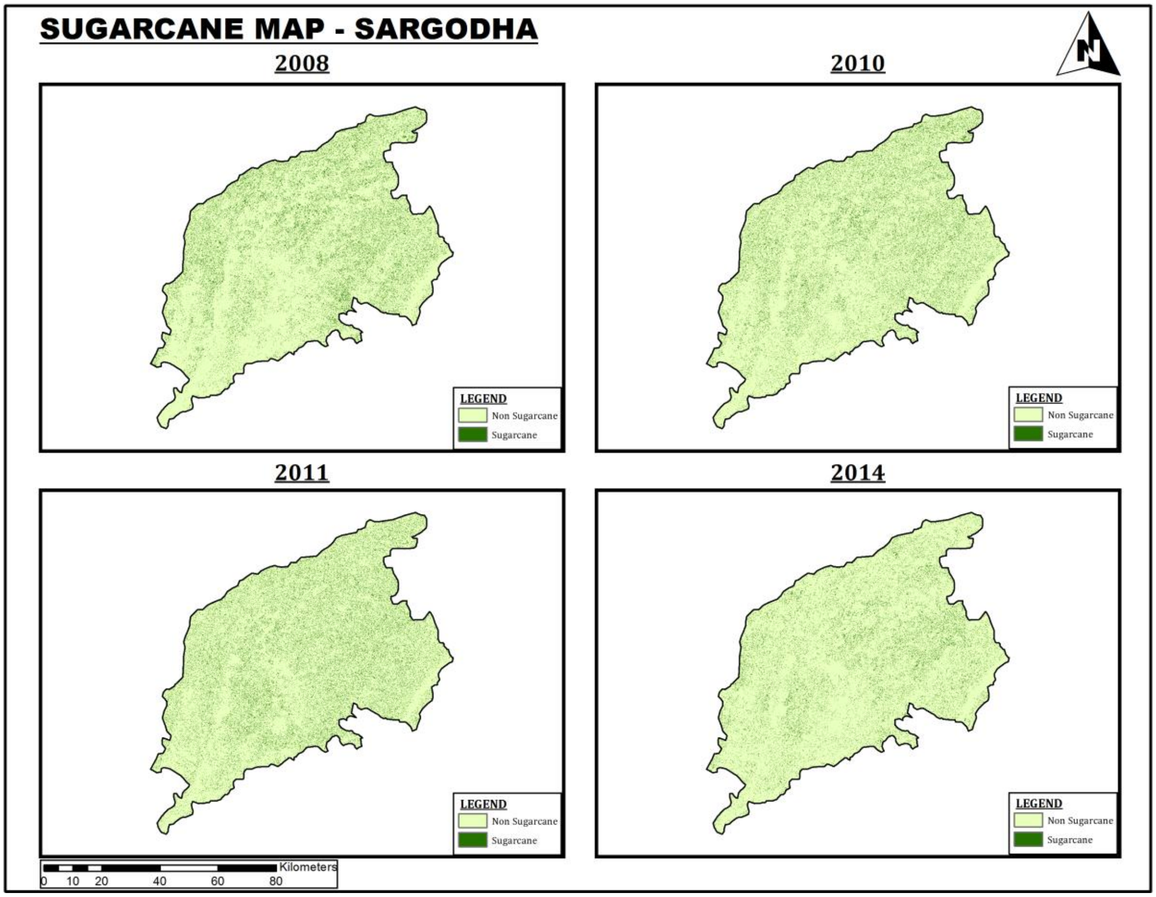


Figure 3.16: Sugarcane maps Sargodha district

3.4.3 Mapping of sowing trend for sugarcane crop

After determining sugarcane and non-sugarcane areas sugarcane sowing trend map for the Punjab province for the years 2008 to 2014 was prepared (Figure 3.17).

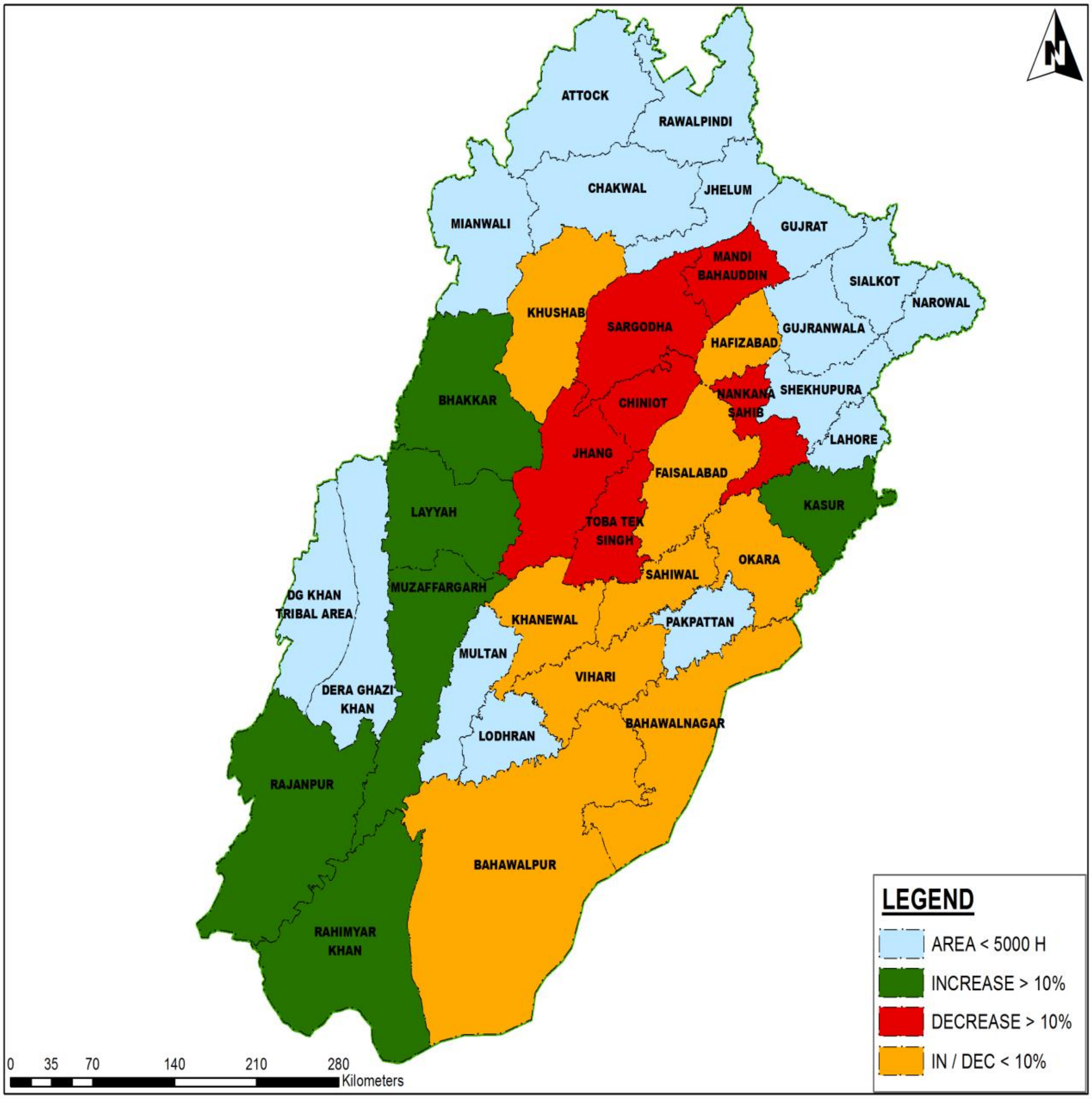


Figure 3.17. Sugarcane sowing trend map

3.5 Socio-Economic causes of the sugarcane sowing trend

Two main districts were selected, in one of those the sowing trend was on the increasing side and in the other area of sugarcane had been decreasing over the years. A comprehensive questionnaire in the local language was prepared and about 74 farmers from 45 different villages and 5 different tehsils of the two districts were interviewed and asked to fill up the questionnaire following the methods of (Ahmad, et al., 2014). These farmers grew different crops like wheat, sugarcane, rice and cotton. In the questionnaire each crop cycle was divided in four different stages which include land preparation, seeding, irrigation, fertilizers, weed removal and harvesting & transportation. The farmers were asked about their expenses at different stages of crop growth and development, incomes and their net gains were calculated for each crop. In case of sugarcane additional questions were asked regarding variety of sugarcane, distance to sugar mill, attitude and behaviour of sugar mill staff and whether support price of sugarcane recommended by government is sufficient or not (Appendix 1). The answers given by farmers were critically analysed and inferences were drawn from these (Appendix 2-5).

Chapter 4

RESULTS AND DISCUSSION

In this study, the appropriate time for identification and mapping of sugarcane was identified based on the temporal analysis of RS data and derived NDVI values. The months of November and December were identified as the appropriate months for mapping sugarcane, having a range of NDVI values between 0.24 and 0.34. Some of the miscellaneous areas like grass, open green space and fodder had NDVI values closer to that of sugarcane. There was a possibility of confusion amongst the two sub classes of the vegetation class. To separate the two sub classes definitively, exact locations of all sugarcane fields were required, perhaps on a geographical map of the study area. However, no such official map was available and the study area was too large to be surveyed. The project was continued despite this limitation and partial ground truthing was done to assess accuracy. For 21 districts, the areas of sugarcane were calculated from the classified images (Table 4.1 and figure 4.1-4.2).

Table 4.1. Sugarcane area in districts of Punjab from 2008 till 2014

Year/ District	Area (Hectares)						
	2008	2009	2010	2011	2012	2013	2014
Rajanpur	10012	10917	12591	16594	12994	CC	18914
Sargodha	61602	CC	59229	67265	52723	CC	44897
Muzaffargarh	34624	20287	26062	40249	41965	CC	40234
Faisalabad	98231	CC	97001	102985	102763	CC	102733
Bhakar	16784	13624	17676	19911	20646	CC	21182
Bhawalnagar	13638	CC	16135	12567	13032	CC	14056
Bahawalpur	17188	14967	18619	20149	18010	CC	19229
Jhang/ Chaniot	88812	CC	92652	79467	83389	CC	75933
Kasur	36646	CC	39758	39684	47686	45228	49603
Layyah	13347	8861	10759	10252	9832	CC	18411
Mandi Bahaudin	29400	CC	34598	28326	27440	27255	23130
Nankana Sahib	17232	CC	18073	16120	18280	11876	12692
Okara	20796	18305	19478	21389	18512	21439	22397
Sahiwal	11169	CC	12219	9497	9145	CC	11854
TT Singh	37699	CC	CC	51577	35243	CC	29351
Vehari	10947	CC	CC	15408	14188	CC	19158

CC= Excessive Cloud cover

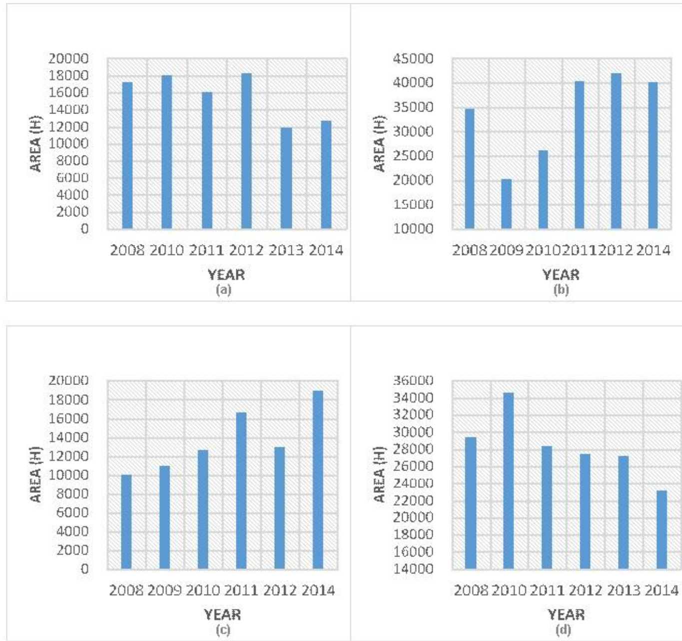


Figure 4.1. Sugarcane area in(a) Nankana Sahib (b) Muzafargarh (c) RajanPur (d) Mandi Bahaudin

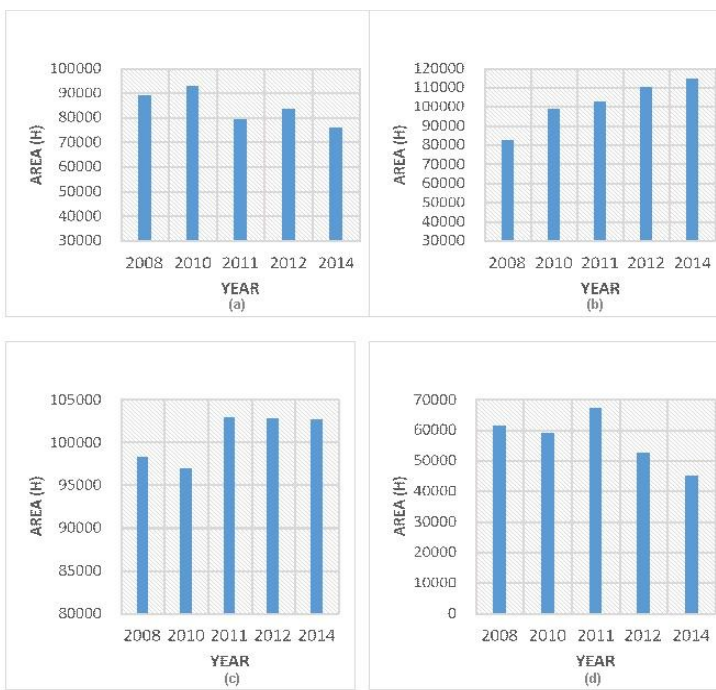


Figure 4.2. Sugarcane area in (a) Jhang/ Chaniot (b) Rahim Yar Khan (c) Faislabad (d) Sargodha

4.1 Quantitative assessment

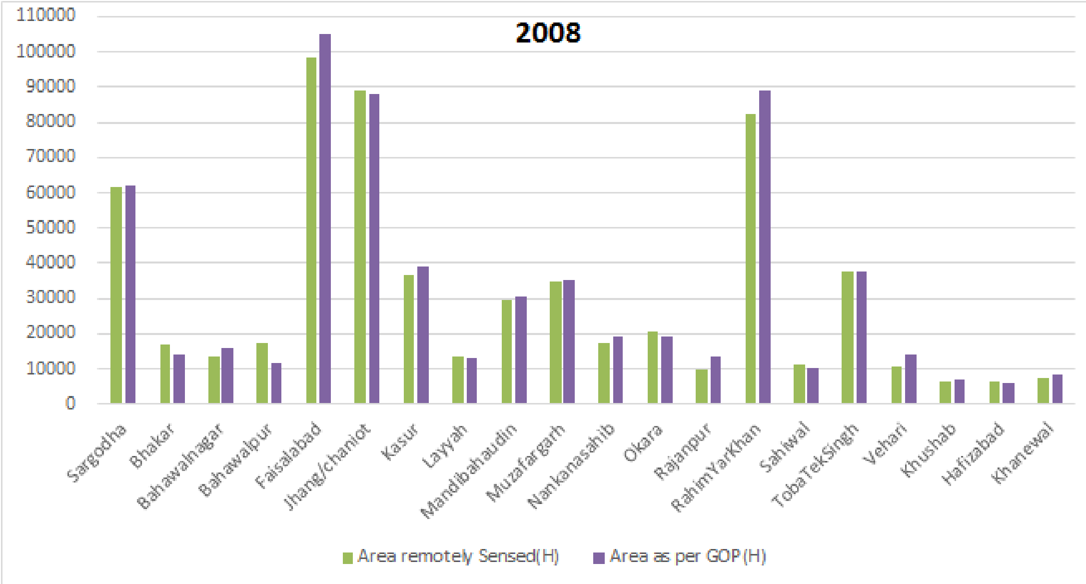
Quantitative assessment was done by comparing area of sugarcane for years 2008 and 2010 derived from remotely sensed data with the available government data published by Government of Punjab (Table 4.2 & Table 4.3). The acreages are estimated by Crop Reporting Service (CRS) through sample surveys and Girdwar surveys carried out by the Patwaris twice every year (Directorate-of-Agriculture, 2006). For 2008 data the overall average similarity between the area detected by remotely sensed data during our study and cropped area released by Government of Punjab (GOP) was 91%. Out of 21 districts 16 districts had more than 90 % similarity, two districts have more than 85 % and three districts (Bahawalpur, Rajanpur and Vehari) had 70%, 74% and 77% similarity. Similarly for 2010 data, out of 21 districts 17 had more than 90% similarity while Bhakar, Bahawalpur, Layyah and Sahiwal had 87%, 82%, 82% and 70% similarity respectively and overall similarity was 92% (Figure 4.2).

Table 4.2. Comparison of sugarcane area acquired from remotely sensed data with available data of GOP -2008

S/No	District	Area remotely Sensed(H)	Area as per GOP(H)	Difference	Similarity
1	Sargodha	61602	62300	-698	98%
2	Bhakar	16784	14200	2584	85%
3	Bahawalnagar	13638	15800	-2162	86%
4	Bahawalpur	17188	11700	5488	70%
5	Faisalabad	98231	104800	-6569	93%
6	Jhang/chaniot	88812	88200	612	99%
7	Kasur	36646	38900	-2254	94%
8	Layyah	13347	13000	347	97%
9	Mandibahaudin	29400	30400	-1000	97%
10	Muzafargarh	34624	35200	-576	98%
11	Nankanasahib	17232	19000	-1768	90%
12	Okara	20796	19400	1396	93%
13	Rajanpur	10012	13400	-3388	74%
14	RahimYarKhan	82388	89000	-6612	92%
15	Sahiwal	11169	10500	669	94%
16	TobaTekSingh	37699	37600	99	99%
17	Vehari	10947	14200	-3253	77%
18	Khushab	6400	6900	-500	92%
19	Hafizabad	6300	6100	200	96%
20	Khanewal	7600	8500	-900	90%

Table 4.3. Comparison of sugarcane area acquired from remotely sensed data with available data-2010

S/No	District	Area remotely Sensed(H)	Area as per GOP (H)	Difference	Similarity
1	Sargodha	59229	59100	129	99%
2	Bhakar	17676	15400	2276	87%
3	Bahawalnagar	16135	15800	335	97%
4	Bahawalpur	18619	15400	3219	82%
5	Faisalabad	97001	104800	-7799	92%
6	Jhang/chaniot	92652	94600	-1948	98%
7	Kasur	39758	39700	58	99%
9	Layyah	10759	8900	1859	82%
10	Mandibahaudin	34598	33600	998	97%
11	Muzafargarh	26062	27500	-1438	95%
12	Nankanasahib	18073	19000	-927	95%
13	Okara	19478	17400	2078	90%
14	Rajanpur	12591	11700	891	93%
15	RahimYarKhan	98942	94300	4642	95%
16	Sahiwal	12219	8500	3719	70%
18	Khushab	6400	6900	-500	99%
19	Hafizabad	5900	5300	600	90%
20	Khanewal	7600	8500	-900	92%



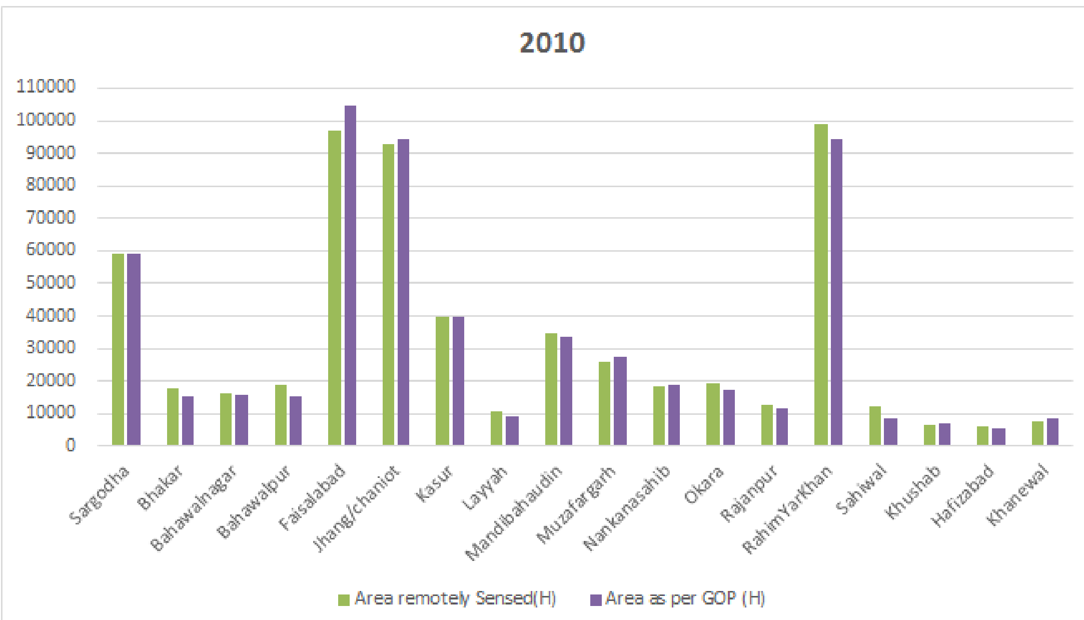


Figure 4.2. Comparison of sugarcane area assessed by remotely sensed data with data available with Government of Punjab (GOP)

4.2 Qualitative assessment

For qualitative assessment ground truthing was carried out in some areas of Faisalabad and Hafizabad and GPS references were noted for sugarcane crop fields (Figure 4.3). For Sargodha district we already had the GPS references of the sugarcane crop fields collected at the start of the project. For Faisalabad a total of 23 points were collected and out of those 19 were accurately classified so accuracy was 79 %. For Hafizabad accuracy was 72% out 11, 8 fields were accurately classified. For Sargodha the accuracy was 80% Out of 24 points 20 were accurately classified. (Figure 4.4-4.6). Overall classification accuracy for the study area was calculated to be 77%. There can be two reasons for this lower accuracy value; within-class confusion between sugarcane and other miscellaneous areas or the coarse resolution of Landsat data (i.e. 30m) utilised for the study.

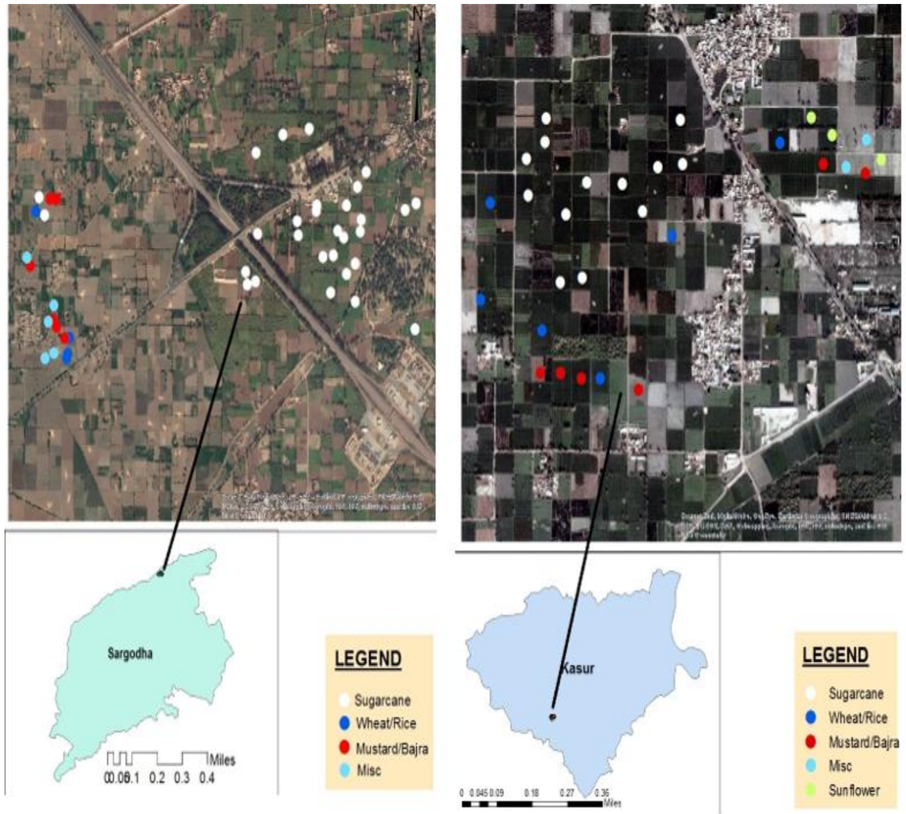


Figure 4.3. Reference locations for ground truthing

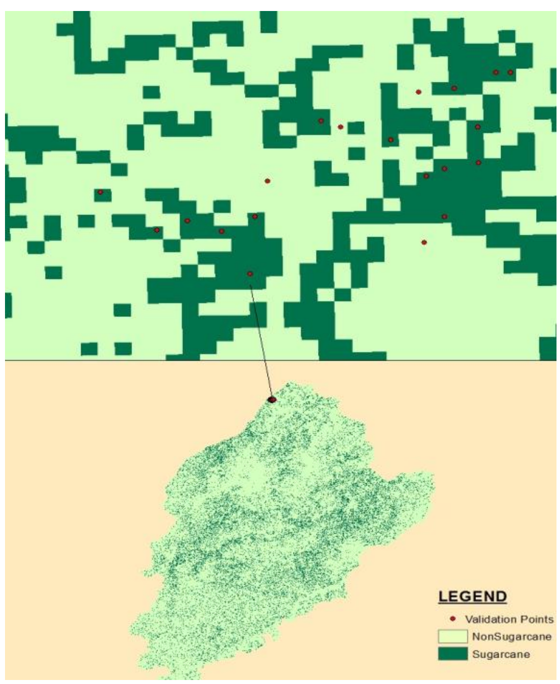


Figure 4.4. Qualitative assessment Faisalabad district

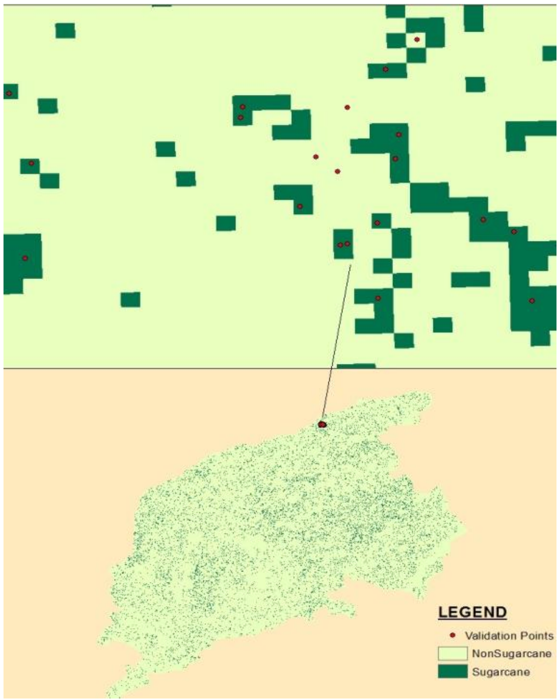


Figure 4.5. Qualitative assessment Sargodha district

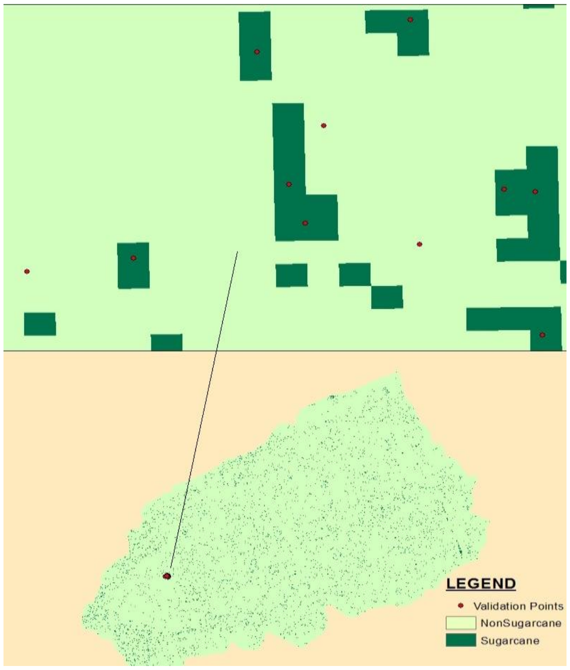


Figure 4.6. Qualitative assessment Hafizabad District

4.3 Sowing trend map zones

In the trend map in Fig 3.17, three different zones of sugarcane areas were identified for the years 2008 to 2014. First zone consisted of districts which showed a decrease of more than 10% in sugarcane area in this time period, while the second zone comprised of districts which showed an increase of more than 10 % in sugarcane area over the same time period. The third zone consisted of districts in which sugarcane area remained the same, i.e. the observed increase/ decrease was less than 10%.

4.4 Socio-Economic causes of the trend

For the analysis of sowing trends adopted by farmers, two districts, Sargodha and Muzaffargarh were selected for survey. In Sargodha, sugarcane area decreased by more than 10% while conversely, sugarcane area in Muzaffargarh increased by more than 10%. Critical analyses of farmer's responses revealed that 100 % of farmers from both districts were not satisfied with support prices recommended by the government. These farmers had serious concerns about the dealings and non-courteous behaviour of the sugar mill administration. The farmers revealed that they are often forced to wait 3-4 days to unload and weigh the sugarcane. Such intentional delays not only cause the sugarcane to dry up but also increase crop transportation costs.

From the farmer's responses it was learnt that average distance from the sugarcane field to a sugar mill is 25 km but there are no defined feeding areas for the sugar mills. This was also confirmed when the average distance from sugar mill to field was plotted for each sugar mill in district Faisalabad (Fig 4.7). It was observed that the estimated feeding areas often overlap and tend to extend into adjacent districts. However, the overall production levels of sugarcane were in accordance with estimated capacity of the sugar mills. The sugarcane area of 97933 Hectares was required as per capacity of sugar mills and a total of 102733 Hectares was estimated from remotely sensed data. (Table 3.2).

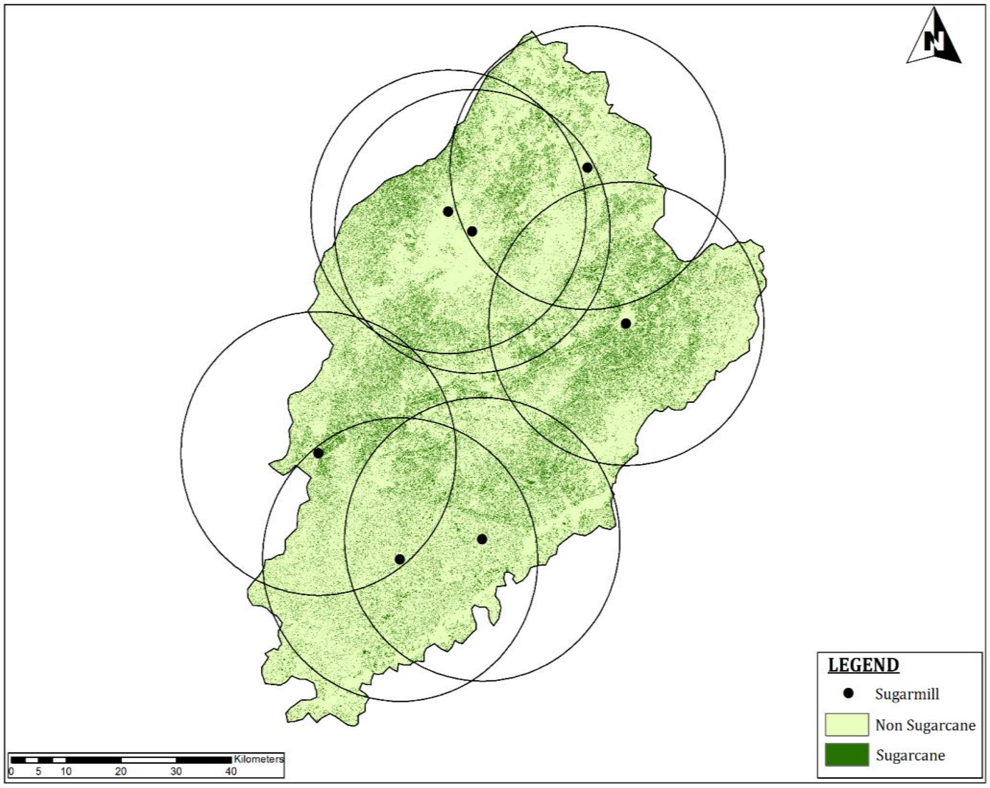


Figure 4.7. Anticipated feeding areas of sugar mills in district Faisalabad

Table 4.4. Sugarcane area requirement for district Faisalabad as per the capacities of sugar mills

S/no	Sugar mill	Capacity (TCD)	Area of sugarcane req (Acre)
1	Hunza Sugar Mill	8000	32000
2	Crescent sugar mill	3000	12000
3	Madina Sugar Mills	10000	40000
4	Chanar sugar mill	6000	24000
5	Tandlianwala Sugar Mill	15000	60000
6	Shamim Sugar Mill	8500	34000
7	Husein Sugar Mill	10000	40000
Total Area Req		**242000 Acre = 97933 Hectare**	

The other aspect was the payment made to the farmers though the support price recommended by the Government of Punjab was Rs 180/- per Maund for year 2014. (Maund is the unit in which dealings are made in Punjab, Pakistan and it is equal to 40 kgs) but some sugar mills in district Sargodha were paying Rs 175/- per 40 kgs to Farmers and on average Rs 176 /- per 40 kgs was paid to farmers .On the other hand in Muzaffargarh the average payment per Maund was Rs 179/-. Another issue is of timely payment to the sugarcane growers, in Sargodha on average payments are made to farmers after the lapse of 9 months and some mills are paying even after 12 months. In Muzaffargarh the situation is much better where payments are made within 3 months on average. (Table 4.4). Government has increased support price from Rs 150/- to Rs 180/- from 2012 till 2014 (SPBP, 2012).In 2012 the support price of sugarcane was Rs 150/- per 40 kgs whereas support price of rice is Rs 1250/- and Rs 1000/- for rice Irri. Support price of rice remained constant since 2012. The net gains earned by sugarcane growers in 2012 were even lesser than in 2014, confirming the results achieved by (Ahmad, et al., 2014; Nazir, et al., 2013).

The relative earnings and gains per acre for all the major crops in the study area were also compared (Table 4.5). The combined per acre per annum earnings of wheat _ rice, wheat _cotton and sugarcane are compatible with each other. However overall, these earnings are still very low in view of the current inflation in prices of daily commodities. The average landholding in the study area is about 10 acres and an average per month per acre earnings of 35$ is insufficient for fulfilling basic life necessities.

Table 4.4. Comparison Sargodha Vs Muzaffargarh

S/No	Item	Muzaffargarh	Sargodha	Remarks
1	Average Payment Per 40 kgs (Rs)	179	176	Govt recommended price is Rs 180
2	Average Profit Per 40 kgs (Rs)	55.5	46	
3	Average Time Taken By mill to Pay Farmers	3 months	9 months	Max is 12 months by some sugar mills in Sargodha
4	Average Time of wait at mill	4 days	4 days	
5	Average yield (40 kgs)	773	769	

Table 4.5. Relative earnings and profits per acre for all the major crops in the study area

S/No	Crop	Average yield Per Acre (kgs)	Profit Per 40 kgs (Rs)	Profit Per Acre (Rs)	Remarks
1	Wheat	1280	441	14112	
2	Rice (Basmati)	1960	337	16513	
3	Rice (Irri)	2680	335	22445	
4	Cotton	1040	962	25012	
5	Sugarcane	30800	49	**37730**	
6	Wheat+Rice(Basmati)	_	_	**30625**	
7	Wheat+Rice(Irri)	_	_	**36557**	
8	Wheat +Cotton	_	_	**39124**	

Chapter 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

As a case study, this research was carried out for identifying and mapping of sugarcane fields in Punjab Pakistan. The study aimed to know the sugarcane sowing trend adopted by farmers for past seven years. The causes of sowing trend were also determined through a questionnaire. The NDVI approach was used to classify sugarcane fields using Leica Geosystem's Erdas Imagine ™and ESRI'S ArcMAP and ENVI.

This study shows that remote sensing has a lot of potential to identify and map sugarcane fields. Spatial and temporal domain of sugarcane can be exploited to identify sugarcane fields. In the study area November and December are the appropriate months to identify and map sugarcane fields. Sugarcane fields has range of NDVI from 0.24 to 0.34 during month of December and November.

As there is no study conducted following remote sensing approach for identifying and mapping sugarcane fields in Punjab, Pakistan using GIS techniques so far, this study will be useful for organizations and sugar mills for sugarcane crop management. This study is also significant because facts on sowing trend adopted by farmers are valuable to the experts and planners who are concerned with the management of crops in the country.

Support prices recommended by GOP for different crops are too less and need revision. Presently there is no comprehensive policy regarding how payments will be made to farmers. At present there are no feeding zones defined for sugar mills.

5.2 Limitations

- No paper / digital maps of sugarcane fields are available for comparison with the maps generated from remotely sensed data.
- More detailed and complete study area surveys and past reports on sowing trend by farmers could have helped in getting more sophisticated results. Consequently, the results with these restrictions, may not be 100% accurate but gives a fair idea of the sugarcane area and sowing trend in Punjab province of Pakistan. These results can be set as a base for further revised research(s) and management efforts.
- It is suggested that NDVI results should be verified with on-ground verification in all sugarcane districts of Punjab to attain more accuracy but selected study area was too large to be surveyed.
- Non availability of high resolution data is another limitation therefore medium resolution data was used

5.3 Recommendations for Further Research

- There is a need to incorporate remotely sensed data in our crop yield estimates.
- Research can be repeated using high resolution data which can improve the results a great deal.
- Moreover, with its flexibility the methodology can be implemented as a whole for sugarcane crop management projects in Sindh province with some minor edits.
- There is a need of revising the support prices of different crops, recommended by Government or major inputs need to be subsidized so there can be substantial increase in net gains of farmers.

- Decision makers and investors can preferably use this technique for improved crop management projects.
- There is a need of a comprehensive policy regarding methods and mode farmers be dealt at the sugar mills and how payments will be made to them. We need to set the time frame during which payments must be made to farmers.
- Zoning system should be introduced. Each mill should have a zone, which should match the capacity of sugar mill. Mills must not be allowed to procure sugarcane outside its zone. Only after finishing cane of their own zone, they may be allowed to obtain cane from outside. The mills should be provided incentive in increasing their milling capacity if they improve the cane yield of their zone.

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APPENDICES