Comparative Study of Conventional and Satellite Based Agriculture Information System

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Abstract—The purpose of this study is to compare the conventional crop monitoring system with the satellite based crop monitoring system in Pakistan. This study is conducted for SUPARCO (Space and Upper Atmosphere Research Commission). The study focused on the wheat crop, as it is the main cash crop of Pakistan and province of Punjab. This study will answer the following: Which system is better in terms of cost, time and man power? The man power calculated for Punjab CRS is: 1,418 personnel and for SUPARCO: 26 personnel. The total cost calculated for SUPARCO is almost 13.35 million and CRS is 47.705 million. The man hours calculated for CRS (Crop Reporting Service) are 1,543,200 hrs (136 days) and man hours for SUPARCO are 8, 320hrs (40 days). It means that SUPARCO workers finish their work 96 days earlier than CRS workers. The results show that the satellite based crop monitoring system is efficient in terms of manpower, cost and time as compared to the conventional system, and also generates early crop forecasts and estimations. The research instruments used included: Interviews, physical visits, group discussions, questionnaires, study of reports and work flows. A total of 93 employees were selected using Yamane's formula for data collection, which is done with the help questionnaires and interviews. Comparative graphing is used for the analysis of data to formulate the results of the research. The research findings also demonstrate that although conventional methods have a strong impact still in Pakistan (for crop monitoring) but it is the time to bring a change through technology, so that our agriculture will also be developed along modern lines.

Keywords—Crop reporting service, SRS/GIS, satellite remote sensing/geographic information system, area frame, sample frame.

I. Introduction

PAKISTAN is an agricultural country, and thus, agriculture is the 'backbone' of the economy and the support of our national economic life. About 70% of the country's population depends upon agriculture. For agricultural countries, crops yield is a major economic source. Pakistan over long periods of time was following both old and manual techniques to estimate crop statistics.

Estimation of crop yields plays a vital role at both the national and regional level. Due to the increase in populations, the demand for crop insurance as well as micro-level planning has also intensified. In economic development, crop yield estimation plays a significant role [1], [2].

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Mostly, the data were collected through manual field surveys and statistical techniques were applied to emulate results, however, these techniques were lacking in one aspect or the other. For systematic agriculture development planning and strategy formulation, precise and on-time information about crop size and area is the basic requirement. The main constraints in collection of data are excessive time lags, quality concerns and a heavy overhead expenditure on man power and ability.

With the introduction of SRS/GIS technology in agricultural sector, the Ministry of Food, Agriculture and Livestock (MINFAL) authorized the Pakistan SUPARCO to devise a satellite based crop reporting and forecasting system in 2005 for gathering of crop statistics and to overcome the shortcomings of the conventional system [3].

There are two major cropping seasons in Pakistan [4]:
a) Rabi Crops are sown from October to December and are reaped from March to April.
b) Kharif crops are sown from Feb to July. The harvesting of these crops starts in September and continues until December, with the exemption of sugarcane that can continue up to March or even beyond.

The purpose of this research is basically the comparison of the two methods of crop monitoring which are currently being used in Pakistan that are: Conventional methods and SRS/GIS methods. This research will highlight which method is better in terms of time, cost, man-power, efficiency, and reliability.

II. Conventional Crop Monitoring System

For many years crop monitoring has been very significant for the government. Initially CRS was developed in the 60s under the Agricultural Extension Department of the provinces. In the late 70s, the Punjab government decided to establish an independent "Crop Reporting Service". The technique used by the PCRS (Punjab Crop Reporting Service) for gathering crop statistics is based on area frame and sample frame.

A. Area Frame (PCRS Procedure for Crop Area Estimation)

A small division of total population of data under study is called Area Frame (AF). A small portion of villages, in each district, is selected randomly representing small, medium and large categories of villages, with respect to the cropped area; this is called AF. The maximum number of villages covered in AF for wheat crop in Punjab is nearly 1,200 villages [5]. The AFs are designed at the district level, and the PCRS carries out all gurdawari (field reviews) of these area frame villages. Eventually, several crop reporters are sent, one per area frame

World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
Vol:11, No:3, 2017

village. These crop reporters travel from field to field, and record the specifics of all features of land, including crops, roads, heaps of straw and cotton sticks etc. These reports are of critical importance as they record all the features with land cover area more than 272 ft^2.

For orchards with mixed cropping, the crop area is determined after subtracting the radius of the plants.

Gurdawari (Survey) for each crop is done, at least, two times during growth periods. The first Gurdawari is initially done after/around the end of sowing of a crop. This Gurdawari is carried out to make an early estimation of the area sown under different crops. The second Gurdawari is carried out to analyze the early area estimate for accuracy and eliminate some of the areas. The other objective of the second Gurdawari is to make a thorough estimation of crop production by evaluating positive and negative aspects of crop growth. A third addition Gurdawari, if needed, is planned specially to meet desired requirements and objectives. The area frame data is provided by village crop reporters to the district administration of PCRS. At the district level, the data of all area frame villages is gathered and used to make estimation for the area of the whole district. The area frame results denote a portion of 4-5% of the total area. All information generated at the end is shared with policy makers, planners and other users both in the province and at the country level of public/private institutions.

B. Sample Frame (PCRS Procedure for Crop Yield Estimation)

A statistical sampling design based on random selection of three small parcels of area 15*20 feet, duplicated twice, is used to calculate yield of crop. This is called the *sample frame*. Based on these samples, crop cutting and harvesting processes are carried out for the entire village. At the district level, data from villages is collected and used to measure crop yield for the whole district.

The final estimation of crop production is carried out by using the crop yield from the PCRS and area data from the Revenue Department. The Patwari visits every field of the village. In terminal evaluation, the area estimation is taken from the Revenue Department as per the design crop reporting process. Therefore, by practical definition, the data published at the end, shows the area from Revenue Department and yield from the PCRS and the production is a multiple of both.

C. Crops Statistics Reporting Stages

Staff members of the Punjab CRS and Agriculture departments carry out objective surveys in the AFVs (Area Frame Village) [5]. Three types of estimates are made: first, second and final estimate.

a) *First Estimate:* is estimation of the area under crop.
b) *Second Estimate:* is the subjective estimation of crop yield. Crop yield is determined by crop cutting experiments for major crops and by opinion surveys.
c) *Final estimate:* covers both area and production estimates. It consists of area from the Revenue Department and the yield from the PCRS.

III. Satellite Based Crop Monitoring System

MINFAL opted to use SRS/GIS for gathering crop statistics in Pakistan. In 2005, MINFAL SUPARCO, the national space agency, and cooperating departments/organizations as PCRSs, FBS (Federal Bureau of Statistics) and Pakistan Meteorological Department (PMD) were assigned to undertake this responsibility. SUPARCO, under patronage of MINFAL, has developed a satellite based system to monitor the crop sector of Pakistan. The steps involved in SRS/GIS-based SCMS are described in this section.

A. Image Acquisition

The plan for acquisition of 5m imagery for diverse crops is developed, which is as follow [6]:

a) *First acquisition:* Approximately four weeks after Completion of Sowing Time (COST).
b) *Second acquisition:* Approximately eight to 10 weeks after COST value of different crops.
c) *Third acquisition:* At 70% of SPOT (System Pour l'Observation de la Terre) VGT (Vegetation) value of various crops.

B. Image Enhancement

In order to distinguish the land cover features of interest, image enhancement is carried out through a variety of techniques including histogram equalization, standard deviation, Gaussian technique, linear enhancement and convolution filters.

C. Crop Area Estimation by Area Frame

The AF in SRS (Satellite Remote Sensing) is dynamic and changes with changes in land cover. AF in SRS represents 100% of the population in the AOI (Area of interest) rather than a fraction. The sample size in SRS can vary and is called a Segment. SUPARCO developed an AF system for use by satellite-based techniques through stratification.

1. Stratification

Each parcel of land is divided into homogeneous areas called a Stratum. The first step in this process is stratification of the AOI into homogeneous areas. SUPARCO define stratification on the basis of cropping intensity and land cover feature, by digitizing physical boundaries in the satellite images. The segments of size of 6km*6km are placed; at least one in each stratum/image by computer software. This technique places 10 to 20 segments in each district depending on diversity of land cover and size of the district. Each segment represents 1% of the area of one image which is 60 km*60 km. About 0.3% area is covered in each segment during the GTS (Ground Truth Survey) [7]. Table I gives a comprehensive definition of stratification.

The vector layers of the toposheet and satellite images are digitized. All nonagricultural areas of large size such as deserts, water bodies, cities, factories, barren lands and others are excluded through masking process to optimize labor and investment.

World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
Vol:11, No:3, 2017

TABLE I
STRATIFICATION DEFINITION

Stratum	Definition
11	Intense Cropland Area (75-100% Cropland)
12	Less intense crop land (50-75% Stratum)
21	Cropland Pasture Mixed (25-50%)
42	Mostly Pasture (25% cropland)
13	Un-identified Seasonal Vegetation
14	Areas rarely under vegetation
31	Rural area around city (Less than 50 houses\Km square)
32	Inter city
50	Non-farm land (Desert, Forest, Saline, Establishment)
60	Water bodies (Rivers, Canals)

2. Partitioning Area of Interest

A start is made by dividing the AOI into three or four major areas by natural features such as main roads, canals, railway lines or other surface features. Primary and secondary units are formed by are a frame designer.

3. Developing Image Prints

The prints of these segments are printed on a 1:5000 scale in 2.5m image resolution. The toposheets with digital mapping of roads, canals and other important networks is printed on the other side of the prints with segments to provide guidelines for locating segments in the field [8].

4. Gurdawari by Crop Enumerators

Crop enumerators, whom boundaries of segments are assigned, carried out a gurdawari of the segments by the standard procedures defined in the field schools/CRS procedures. Within a given zone, field information is extracted from the gurdawari.

5. Simulation of the Field Information

The data generated in the field are compiled in the laboratory. Following, further works are carried in the field information, including:
a) Extraction of area information from the raising factor.
b) Extraction of spectral signatures from the training sample.
c) Image classification using spectral signatures.
d) Estimation of the area of crops from the classified image.

6. Calculating Raising Factor(RF) to Estimate Area of Crops

The area sown under wheat is worked from the Gurdawari using the RF technique according to (1) [5]-[7].

$$R.F = \sum \{Across\ zone\} \frac{\sum[Area\ of\ a\ given\ stratum]}{\sum[\ Area\ of\ the\ stratum\ across\ segments]}$$

$$Crop\ area\ in\ a\ stratum = R.F \times \sum(Area\ of\ the\ crop\ across\ segments) \quad (1)$$

7. Ground Truth Surveys

The AOI was divided in four zones for the wheat crop, depending on the number of districts under study. Each zone generally consists of geographically connected/close 4-5 districts. Four properly trained teams of 2-3 professionals each is given the responsibility to carry out GTS one in each zone. These teams carry hard and soft copies of the images, duly orthorectified.

The GTS for a particular village is initiated almost 5 km ahead of the village under survey and continued beyond 5 km beyond the village. In general, the GTS is conducted among all the roads present in that village.

Special investigation is made for those points which seemed blurred in the imagery. In most of the villages, a 50 acre block is highlighted by coordinates to evaluate the area estimation by satellites to the ground data estimated through field surveys.

The comparison of satellite and ground data is used to find out a correction factor for refinement of satellite data [9]. This technique is needed, as on ground procedures of crop reporting surveys excluding all areas in the fields which are irrelevant to that crop. The information gathered from the field is digitized in each segment.

D. Image Classification

For image classification, the desert areas are excluded from the image in all districts, and organized classification is carried out using maximum possible techniques.

Development of accurate spectral signature is the most vital step in land cover classification [10], [11]. The clear and un-blended representative training samples from the ground truth materials are drawn and are used as spectral signatures of two different dates.

Image classification is carried out by supervised classification using Gaussian maximum likelihood method on different work units and area estimation was carried out using ERDAS (Earth Source Data Analysis System) imagine software [4].

The wheat area is estimated by image classification, based on the training samples drawn from the segments.

E. Analysis and Processing of Imagery

The data gathered from the field are analyzed and processed as:
a) The index of first and second acquisition of the area of interest is developed using software.
b) Work units are developed by crossing the two index files of the first and second acquisitions to minimize over-estimation. The sub sets of first and second acquisition imagery are extracted using work units. The sub sets of first and second acquisition of the same AOI are stacked together to improve the image features.

F. Crop Cut Sampling Techniques for Yield Estimation

Crop cut data is a vital component of multiple regressions modeling for crop yields [12]-[14]. An effort is made to gather data from the CRS. The source of all crop yield forecasting methods is the long time series of historical yield data. In this case, the official wheat statistics data at the country, province and district level is used. The district level yield data has been available for Punjab since 1986.

Basic information used for the examination in forecasting includes land cover imagery of the AOI, SPOT VGT archive and current data, historical crop data/trends, meteorological

World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
Vol:11, No:3, 2017

data, crop water requirement and irrigation water availability [15].

IV. RESULTS AND ANALYSIS

Conventional and satellite based crop monitoring systems are evaluated on the basis of three parameters:
a) Man power.
b) Cost.
c) Time.

A. Manpower

The results show that CRS has manpower of 1,418 people, whereas SUPARCO only has 26 people for performing the same tasks. A comparison of manpower of CRS and SUPARCO, as shown in Table II, clearly shows that Punjab CRS has 1,392 (1,418-26) workers more than SUPARCO for carrying out the same tasks. The major difference is among the crop reporters, they constitute 73.20% (1038 crop reporters) of the total manpower of CRS, whereas SUPARCO has no crop reporters. The difference between CRS and SUPARCO manpower is more than 50%. It is calculated as:

Difference in manpower = Total manpower of CRS/Total manpower of SUPARCO

Difference in manpower = 54.54 times

CRS has almost 54 times more workers than SUPARCO which means that SCMS is efficient in terms of manpower, as compared to conventional crop monitoring system.

B. Cost

The total cost calculated for SUPARCO is almost 13.35 million and CRS is 47.705 million. The total cost calculated

includes direct cost (cost on salaries, equipment cost, vehicles cost and travelling cost) and indirect cost (expenditure spent outside the organization). Table III shows the cost comparison of CRS and SUPARCO. The results show that the total cost for Punjab CRS including the cost on salaries, cost on equipment, vehicles cost and cost on travelling is Rs. 120,801,000/-, whereas the cost for SUPARCO is Rs. 22,161,000/- . The indirect cost calculated for SUPARCO is: Rs. 222000/-.

The cost difference for both systems is: 120,801,000/ 22,161,000, which is approximately 5.5 times. It means that Punjab CRS cost is 5.5 times more than the cost of SUPARCO, which indicates that SCMS is efficient in terms of cost as compared to conventional crop monitoring system.

TABLE II
COMPARISON OF MANPOWER OF CRS AND SUPARCO

Designation	CRS Frequency	CRS (%)	SUPARCO Frequency	SUPARCO (%)
Director	1	0.07	1	4.00
Consultant	0	0	1	4.00
General Manager	0	0	3	11.54
Assistant Director	45	3.17	0	0
Manager	0	0	6	23.08
Assistant Manager	0	0	8	31.00
Statistical Officer	156	11.00	0	0
Statistical Assistant	166	11.70	0	0
Crop Reporter	1038	73.20	0	0
Scientific Assistant	0	0	3	11.54
Computer Operator	0	0	1	4.00
Data Entry Operator	0	0	3	11.54

TABLE III
CALCULATION OF MAN_HOURS FOR SUPARCO DIRECTOR

Duties at Division level	Persons	Dec		Jan	Feb	Mar				Hours
Satellite Image Acquisition Planning		40	20							60
Ground Truth Survey Planning	01	20	40							60
Satellite Image Classification						40	40	20	20	120
Agriculture Results Finalization								20	20	40
Total										**280**
Grand Total (8 Hours per day & 5 Days per week)										**280**

TABLE IV
COST COMPARISONS OF CRS AND SUPARCO

Cost on	Punjab CRS	SUAPRCO
Salary	47,705,000	1,335,000
Equipment Cost	3,321,000	3,284,000
Vehicles Cost	69,775,000	15700000
Travelling cost	0	1620000
Indirect Cost	0	222000
Grand Total	**120,801,000**	**22,161,000**

C. Time

For calculating time: man hours for Punjab CRS and SUPARCO are calculated. The following technique is used in the research to calculate total man-hours:
a) Determine the man power involved in the project.
b) Divide the work into job classifications.

c) Look at the calendar and remove all the non-working days from the work time period.
d) Calculate how many hours it would take to complete each individual job from start.
e) Each job classification's man hours totals together to get the final estimate of man hours required to complete the entire project.

Calculation of man hours of SUPARCO director is presented in Table III. The time of both systems is calculated by calculating the man hours of each individual involved in the process. The man hours are calculated by using a technique which is described earlier. The results are shown in Table V and Fig. 1.

The total man hours for Punjab CRS are 1,543,200hrs. The total man hours for SUPARCO are 8,320hrs. The difference is

World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
Vol:11, No:3, 2017

of 1,534,880hrs, which means that CRS workers work 1,534,880hrs more than the SUPARCO workers.

a) Activities are performed simultaneously (SUPARCO): 8,320/26 = 320 hours.
b) We are considering 8hrs per day: 320/8 = 40 days.
c) 26 employees of SUPARCO finish their work in 40 days.
d) Activities are performed simultaneously (Punjab CRS): 1,543,200/1,418 = 1,088 hours.
e) Again we are considering 8hrs per day: 1,088/8 = 136 days.
f) 1,418 workers of Punjab CRS finish their work in 136 days.

TABLE V
COMPARISON OF MAN-HOURS OF SUPARCO AND PUNJAB CRS

Level	CRS Frequency	SUPARCO Frequency	CRS Man Hours	SUPARCO Man Hours
Director	1	1	1,360	280
Assistant Director	45	0	61,200	0
Consultant	0	1	0	280
General Manager	0	3	0	400
Manager	0	6	0	2,640
Assistant Manager	0	8	0	2,400
Statistician	12	0	16,320	0
Statistical Officer	156	0	212,160	0
Statistical Assistant	166	3	17,2640	1,040
Computer Operator	0	1	0	200
Data Entry Operator	0	3	0	1,080
Crop Reporter	1,038	0	1,079,520	0
Grand Total			**1,543,200**	**8,320**

TABLE VI
SUMMARIZED RESULTS OF COMPARISON

S. No.	Parameters	Punjab CRS Result	SUPARCO Result
1	Manpower (Persons)	1,418 employees	26 employees
2	Cost (Millions)	Rs. 120,801,000/-	Rs.21,939,000/-
3	Man hours (hours&days)	1,543,200hrs or 136 days	8,320hrs or 40days

Difference in man hours =1,088/320 = 136/40 = 3.4 times which means SCMS is efficient in terms of cost as compared to conventional crop monitoring system.
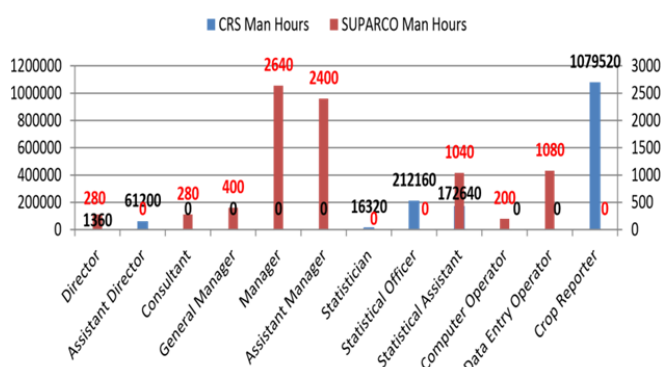

Fig. 1 Comparison of man-hours of SUPARCO and Punjab CRS

Summarized results of comparative analysis are presented in Table VI.

V. CONCLUSION

This study has been focused on comparing conventional crop monitoring system and satellite based crop monitoring system of Pakistan on the basis of several parameters like: man power, cost and time.

It has been revealed from the research that conventional methods used for crop monitoring are time consuming, expensive due to field surveys, and engaged huge man power and provide production estimates after harvesting. The validity of information collected from Patwari or provided by crop reporters is another major drawback of the conventional system. The major reasons are the failure of the patwari and crop reporters to devote adequate time and attention under the conventional method and under reporting of the area.

The current research will be useful for decision makers to build such a system that will focus on how the agriculture sector will be developed along modern lines and how agriculture statistics can be strengthened in Pakistan using SRS/GIS techniques.

As accuracy of the estimates of food production is predominantly dependent on the accuracy of the crop acreage estimate, SRS/GIS techniques would help in generating more accurate data on food production. The satellite remote sensing and GIS technology has facilitated to overcome the limitations of the manual system. This technique has been useful to supply data of high quality in advance of crop harvests and facilitate the policy makers, public/private sector and end users.

This study can be further extended to other provinces of Pakistan other than Punjab. Crops other than wheat can also be the part of the study.

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World Academy of Science, Engineering and Technology
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