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A review of potential use of geo-information technologies for cotton supply chain management

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In this paper, we provided an overview of the cotton supply chain management (SCM) and its processes including their inputs/ and outputs. The components of cotton SCM were discussed with their influencing factors. Additionally, we searched relevant literature on the potential use of Geographical Information Technologies (GITs) in cotton supply chain management. According to our findings, there is no study on the utilization of the web to maximize potential of GITs in all components of cotton SCM. GITs are, however, successfully used in intelligent data creation, data management, spatial analysis, agricultural decision support system and partially in supply chain management systems. We found a dire need to integrate applications of GITs in all components of cotton SCM to optimize the use of resources as agriculturalists are utilizing GITs in precision agriculture.

Key words: Cotton supply chain management (CSCM), geographic information system (GIS), geo-information technologies (GITs), crop yield estimation, remote sensing (RS), agriculture.

INTRODUCTION

The cotton supply chain management (CSCM) is a complex system and involves many stakeholders. Sustainable demand and supply require the full participation of each player throughout the chain. Generally, a supply chain involves the processes of converting raw materials into manufactured goods and then to consumers' products. In cotton supply chain, a number of stages are involved; starting from cotton growing, picking, ginning, spinning, knitting or weaving yarn to fabric, conversion of fabric into a final commodity, distribution, selling and then the usage of the product. The primary objective of this review is to understand the complex chain of cotton supply, its components and evaluation of the potential use of GITs in the process. Once the understanding is developed, the potential use of GITs evaluated for improvement of cotton SCM as an outcome.

Cotton supply chain

Both "Components" and "Processes" are essential and integral parts of a supply chain. In addition to the components and processes, there are financial and other

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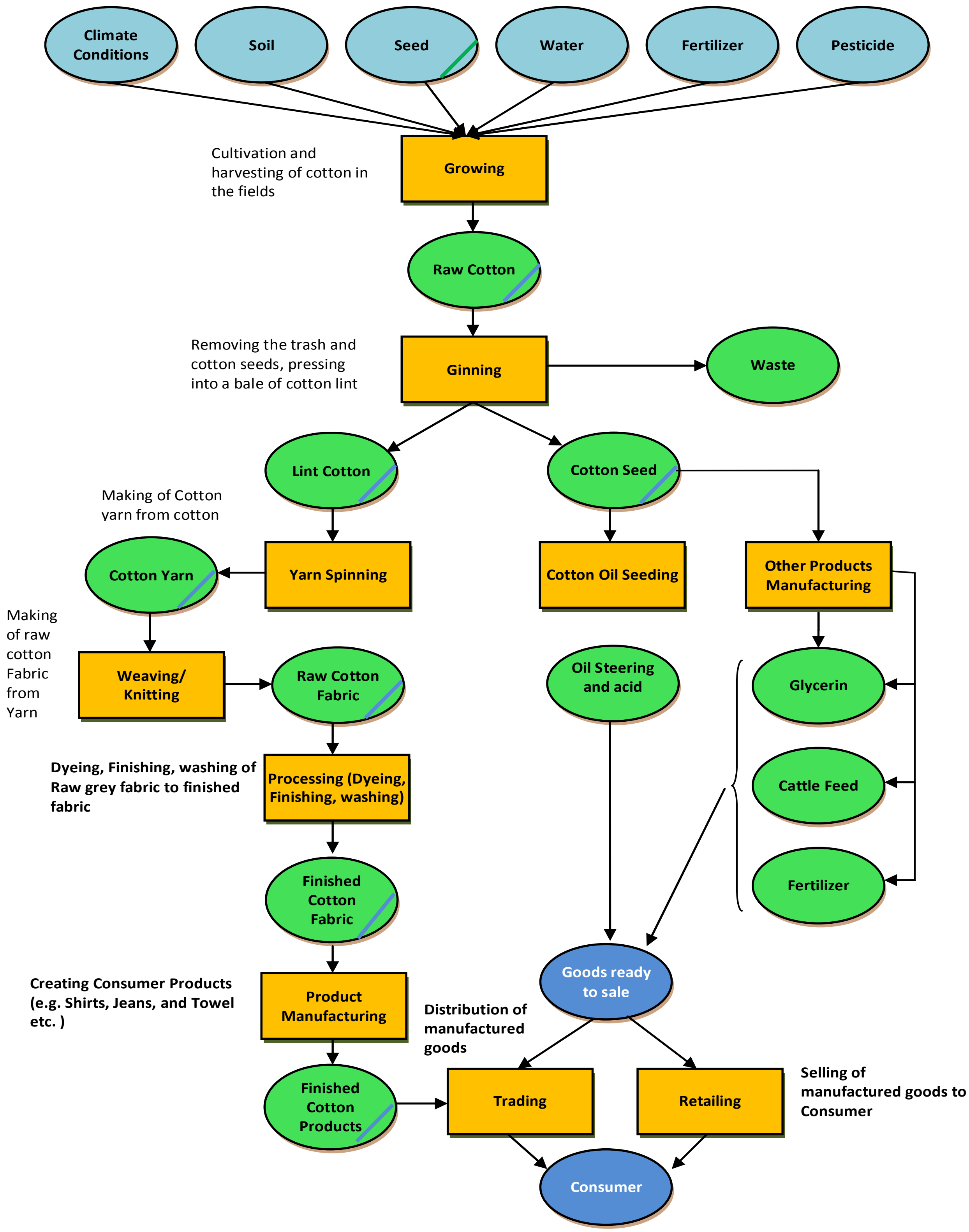

Figure 1. Cotton supply chain.

factors that affect the cotton supply chain. Figure 1 explains the processes of the cotton supply chain with their inputs, outputs and flows marked with arrows.

The purpose of SCM of any commodity is for its sustenance, done by avoiding unrealistic efforts, logistics and losses. Bhan et al. (2010) rated agricultural sustainability as the highest priority throughout the world both in developed or in developing countries Geo-Information Technologies are emerging as useful tools in agricultural sustenance through better management and development strategies. Lal and Pierce (1991) highlighted that the objective of sustainable agriculture is to retain the balance between inherent land resource and crop requirement, which is dependent on sustaining production through optimum utilization of land resource for long period.

Geographic information technologies (GITs)

Shanwad et al. (2004) categorized GITs in precision agriculture into five major groups: Computers, Geographic Information System (GIS), Remote Sensing (RS), Global Positioning System (GPS) and Application control. The subject of Precision Agriculture covers a wide range of issue like variability of the soil resource base, climate conditions, plant genetics, spatio-temporal diversity of crops, machinery performance, irrigations performance and scheduling; crop health and stress assessments; performance evaluation of pesticides and fertilizers; spatial variability of pests and other crop diseases; yield forecasting and production estimations etc. Precision agriculture must fit the needs and capabilities of the farmer and must be profitable. Therefore, there is a strong need to understand the applicability of GITs in every sector of agricultural supply chain management to lower the risks of shortfall and to manage the sources. Dailey (2010) acknowledged in his article that GIT serves as a valuable tool in Supply Chain Risk Management (SCRM) due to its visual analysis. It eventually helps managers and decision makers to prepare for response to any risk/threats in their supply chain operations.

Zhang et al. (2002) discussed the benefits of the technological advancement of current industrial age for agriculture production systems. Mechanization and synthesized fertilizers used for agriculture production systems gained due to this industrial age advancement. Genetic engineering and automation are available in this technological age. GITs potentially used in precision agriculture are used in the information age by integrating other technological advances (Whelan et al., 1997). Spatial and temporal variability are now analyzed by applying advanced geostatistical methods (Pena-Yewtukhiw et al., 2000). Werner et al. (2000) explored the incorporated crop-modeling techniques for fertilizer prescription using yield potential maps developed as a base.

SCM functions involve material procurement, transformations of materials into intermediate and finished products, and then the delivery to customers. For Cotton Supply Chain Management, GITs are tools that can be used to forecast cotton production, map acreages, ginners, spinners, manufacturers, warehouse locations, retailers and distribution centers, and routing of vehicles in particular. Additionally, GITs can be used to analyze the influencing criteria of each actor in the supply chain.

MATERIALS AND METHODS

Literature searched

We did a systematic literature search in Google.com and ScienceDirect.com to get extensive knowledge about the cotton supply chain, its components and the potential applicability of GITs in the cotton supply chain management. The literature search period was from July 2009 to May 2010. The “Cotton Supply Chain in Sindh”, ‘‘GIS in Cotton Supply Chain’’, ‘‘Remote Sensing and GIS in Cotton Supply Chain’’, ‘‘Use of GIS in Cotton supply chain’’, “Supply Chain Management”, Components of supply Chain Management”, “GIS in Ginning Industry”, “GIS in Cotton Transportation”, “GIS in Agriculture” and “GIS and Remote Sensing for Cotton Yield estimations” were the keywords used in this research.

It was not possible to get complete information and knowledge on cotton supply chain contents from research papers. In addition to research work, we used presentations of different conferences, agri-reports and literature available on different URLs of Supply Chain Management Company’s website. In this regard, the identified research papers are limited compared to the literature found in other formats. While searching Cotton SCM, most of the research papers focus on Cotton yield/ Production/Acreage estimation techniques and forecasting. Keeping in view the objective of the study, we included only those research papers, which directly or indirectly discussed GITs in the agriculture supply chain including cotton. Considering the emerging application of GITs in Agriculture and SCM, the literature searched spans from 1995 to 2010.

Identified studies

Five (5) spatial studies of SCM were found in literature and 20 potential GIT studies were extracted in general. However, no studies focus on all components of Cotton Supply Chain Management, instead most of the studies focus on one or a few components of the SCM. Table 1 contains some key findings from Cotton SCM studies.

Fannin et al. (2010) discussed the use of GITs in Louisiana–USA in assessing the spatially variable capability of the cotton ginning infrastructure. For this purpose, they compare cotton field locations with cotton gin locations in spatial canvas by applying Geo-Information technology. Mwasiagi et al. (2008) utilized GIT for cotton yield production in Kenya; they used it to describe agricultural efficiency in the cotton-growing industry. They also applied different spatially enabled resource management methods in this regard. They designed an artificial neural network model to predict cotton yield by using selected cotton-growing cost factors. The performance of the neural network model was satisfactory in predicting cotton yield with minimum errors; a correlation coefficient between network output and actual yield was 0.945.

Simpson et al. (2006) analyzed the transport of cottonseed using GITs in Texas. In this study, Geo-Information Technology was used to route trucks along shortest distance and to decide the quickest or alternate routes to the field and gin area to save time and money. Cotton producing areas, ginning units and transportation network were mapped using ArcGIS by integration of Satellite Images. To analyze the ginning service areas and capability of regional transport (in terms of transport distance and cost), the transport analyst feature in ArcGIS was used.

Sambrani and Subhas (2009) appraised the GITs capability from manager’s perspective for Routing Analysis in Supply Chain

Table 1. Characterization of identified studies for GITs applications for cotton SCM.

Reference	Year	Study area	Data	Methodology	GITs Applied For
Farida Perveen et al.	Accessed on Feb 2010	Bangladesh	Terra/ASTER, SRTM	Multi-Criteria Evaluation (MCE) & GIS approach	Crop Land Suitability
Fannin, et al.	2010	Louisiana	Cotton Ginning statistics, Cotton GIS data	Gin and Cotton Field Distance Analysis	Cotton Ginning Supply Measurement
Bhan et al.	2010	India	GIS Research Literature	Literature Review	Sustainable Agricultural Management
Siva Subramanian	2009	India	IRS Remote Sensing and Market arrival data	Supervised and unsupervised classification with GPS Data, GIS based comparison	Comparison of remote sensing based estimated production with the crop arrival in the market.
Vinod et al.	2009	Dharwad district, India	Transportation, Settlement and Satellite Images	SDSS for route analysis	Routing Analysis in Supply Chain Management (SCM)
Gang Pan et al.	2009	Loess Plateau, China	QuickBird imagery	Integrating QuickBird imagery with a production efficiency model (PEM)	Crop yield estimation
McKiniona et al.	2009	Mississippi, USA	Multispectral imaging using cameras mounted on fixed-wing aircraft	NDVI based spatially variable insecticide application maps	Spatially variable insecticide applications to cotton control insect pests
Pereira et al.	2009	Fergana Valley, Central Asia	Meteorological data concerning precipitation, Crop data, Multiyear soil data	ISAREG model	Irrigation scheduling strategies for cotton
Dong Qinghan et al.	2008	North China Plain	Landsat TM, IRS-P6 AWiFS, SPOT-Vegetation	Hard and Sub-Pixel Classification of RS Data	Crop acreage assessment
Mwasiagi et al.	2008	Kenya	District agricultural data	Artificial neural network model	Prediction of cotton yield
Bandhopadhyay et al.	2008	Nagpur District, India	Remote sensing (Resourcesat-1 LISS III) and spatial agro-climatic data	Infocrop-cotton simulation model	Predicting cotton production
Sharifia et al.	2008	Iran	MODIS/Aqua images and daily meteorological data	Spatial Decision Support System of RS based Bio-Physical Models	Natural Damage Assessment of Crops

Table 1. Contd.

Reference	Year	Study area	Data	Methodology	GITs Applied For
Sharifia et al., 2008	2008	Iran	MODIS/Aqua images and daily meteorological data	Spatial Decision Support System of RS based Bio-Physical Models	Natural Damage Assessment of Crops
Robert	2008	Brisbane, Australia	GIS Research Literature	Analytical review	For precision agriculture and supply chain management
Falkenberg et al.	2007	Uvalde, Texas	Field study & pivot-installed-remote sensing, 30 IRT Data	IRT canopy temperature integration with weather and irrigation data in GIS	Irrigation management of cotton
Nardi et al.	2006	Argentina	Country level Crop & Transportation data	General Algebraic Modeling System, GAMS	Optimization supply chain management of grains
Simpson et al.	2006	Texas	Color near infrared (NIR) aerial photos, Transportation Data	Shortest, quickest distance and cost analysis using ArcGIS network extension	Seed Cotton Transport Analysis
Jayroe et al.	2005	Jonesboro, Arkansas	Aerial images were acquired using multi-spectral camera	NDVI based Classification Method	Crop Production Evaluation
Ferencz et al.	2004	Hungary	Landsat, NOAA, AVHRR	Vegetation Index (General Yield Unified Reference Index (GYURI)	Crop yield estimation
Thomasson et al.	2004	Mississippi	Landsat, 30-m Satellite Data	Gossym cotton growth model	Estimating plant height for Cotton Growth
Shanwad et al.	2004	india	GIS Research Literature	Literature Review	Precision Agriculture
Toulios et al.	2003	Palamas, Greece	SPOT satellite with hand-held radiometer data	Agrometeorological Modeling	Crop Yield Estimation
Ronald et al.	2002	U.S	Landsat 5 and 7 Satellite Images	A Modified Supervised Classification Technique	Crop acreage assessment
Zhang et al.	2002	worldwide	GIS Research Literature	Literature Review	Precision Agriculture
Nadeem et al.	1998	MianChannun	Field data	GIS based surface maps	Spatial analysis of Cotton Leaf Curl Virus
Farhad	1995	Iran	Landsat TM data	Land cover classification	Agricultural Resource Management

Management (SCM) in Dharwad District of Karnataka State, India. The Spatial Decision Support System (SDSS) was developed for this purpose using Visual Basic 6 as the front-end tool with spatial data on transport and settlements. Shortest and alternate path module was developed by modification of the Dijkstra routing algorithm.

Lorimer (2008) explained the usage of GPS from grower to onward processing levels in cropping agriculture chains. Subramanian (2007) presented the idea of GITs Application in Supply Chain Management of agriculture sector. IRS P6 AWiFS satellite images with spatial resolution of 56m were used for agricultural acreage. Medium and high-resolution satellite images of IRS series 1C, 1D, P6 LISS III and LISS IV were used to extract remotely sensed spatial information. Field observations of secondary and primary sources were incorporated such as topography from survey of India - 1:50,000 map series, district wise agriculture statistics and agro-market data from district/state agriculture boards, and farmer's information from sample surveys. The adopted methodology for this study depicts the benefit of GITs based supply chain management as an easy utility for future supply chain management model in complex functions.

Nardi et al. (2006) studied the optimization of supply chain management of grains using ArcGIS in Argentina by applying General Algebraic Modeling System (GAMS). To minimize the transportation and storage costs of soya bean including its by-products, a GITs based constrained linear programming model was developed and successfully implemented.

Sharifia et al. (2008) presented the recent developments in remote sensing technology in biophysical science; they were used to develop an appropriate model for assessment of impacts of natural hazard on agricultural production. For this purpose, a yield model is developed and applied to simulate the biomass production of rice in the growing period. High and low-resolution multi-temporal satellite images were used along with daily meteorological data in the growing period; SEBAL model (Bastiaanssen and Ali, 2003; Zwart and Bastiaanssen, 2007) was also implemented.

RESULTS AND DISCUSSION

It is difficult to discuss all the potential applications of GITs related to cotton SCM. However, discussions excerpted from literature are organized in the following headings: Intelligence data creation; data management; spatial analysis; decision support system; supply chain management system.

Intelligent data creation

To take the right decisions at the right time and for crop cultivation, harvesting, fertilizers and pesticide use, irrigation water management, crop health assessments and yield forecasting, crop acreage estimations, crop market evaluations, supply and demand assessments are few examples of agricultural intelligence data, which are required for sustainable agriculture and supply chain management of agriculture commodity. In the past, an agricultural intelligence data creation involved long surveys with heavy budget and human resource that lacked accurate and timely results most of the time. With the advent of Space Technology, Satellites and GIS tools as GITs are providing fast, less costly and timely results for agriculture decision makers in developed countries where GITs are applied successfully.

GITs also enable supply chain managers to classify satellite images for the identification of crop types in their target areas. The amount and type of energy emitted from each type of crop at each growth stage differs based on the crops. The high-resolution images like the Landsat Thematic Mapper, IRS, Ikonos, and QuickBird are widely used for supervised and unsupervised classifications with a number of spectral indices for delineating crop types in the same agricultural regions for accurate production estimations.

The most critical part of the Cotton Supply Chain management is acreage estimation. The secondary data sources usually based on surveys are by some means costly and inefficient. By applying a number of GITS methodologies with different Remote Sensing data, the areas under cultivation of a particular crop can easily be identified and mapped.

Craig (2002) evaluates the remotely sensed multi-spectral imagery of Landsat 5TM with the Landsat 7 ETM+ to distinguish type of crop and acreage estimation. Comparisons are done for different types of crop areas in several states, using images that are only one day apart. In this study, he used modified supervised pattern recognition to discriminate signature of each type of crop and maximum likelihood for classification and area estimation under each crop in the study area.

Qinghan et al. (2008) also worked on crop acreage assessment in China. This study evaluates the potential application of GITs to estimate large crops. For this purpose, two approaches were applied. Multi-temporal high-resolution images (LANDSAT TM Satellite Images) were classified as the first method. To get better cost-efficient results, the low-resolution satellite images were classified at sub-pixel level as second method. At last, the sub-pixel was classified as SPOT-VEGETATION data calibrated with the hard-classified Land Sat TM Images of 2005, which provided the cost-efficient early acreage estimation methodology through GITs. Similarly, JIAO et al. (2010) provide an efficient and effective method for crop acreage estimation at a national scale in China. Both high and low-resolution data were incorporated with stratified sampling and classification techniques for crop planting area estimation.

In predicting yield, not only acreage and type of crops are important, but also the health of the crop is the prime influencing factor. Through GITs, the water stress areas can easily be distinguished from the healthy crop areas. This involves the emission of different level of energy from healthy and water stressed crops. There are a number of algorithms appraised by different researchers for healthy crop and stress quantification. McKiniona et al. (2009) investigated the spatially variable GITs use for insecticide and identification of tarnished cotton crop insect pests, Lyguslineolaris, plant bugs in cotton fields.

Falkenberg et al. (2007) assessed the commercial instrument of remote sensing managing the biotic and abiotic stress on cotton (Gossypiumhirsutum L.) at specific sites. Canopy temperature of crops is a key indicator of water stress in plants, and can help in developing an efficient irrigation management system (Moran et al., 1997). The deployment of remote sensing data to generate canopy temperature has been useful in examining plant stress (Michels et al., 1999). Bugbee et al. (1999) highlighted the role of Infrared Thermography (IRT) used to investigate leaf temperatures and thermal stress of cotton (e.g. by Burke et al., 1990). Hatfield and Pinter (1993) and Michels et al. (1999) presented the Aerial ''fly-overs'' with installed infrared apparatus, and IRTs with tethered balloons. These are employed for detecting water stress in crops by changes in recorded leaf temperature. Near and thermal Infrared (IR) bands of the electromagnetic spectrum are worked out as remote sensing (RS) tools. To determine plant water stress, Near IR (Nixon et al., 1975; Toler et al., 1981) has measured the reflected light in form of wavelengths. Several researchers appraised Thermal Infrared (TIR) as a useful way to determine canopy temperature, which can eventually help with irrigation scheduling for cotton (Wanjura et al., 1992; Wanjura and Mahan, 1994). Toler et al. (1981), Jackson (1986) and Pozdnyakova et al. (2002) affirmed the use of color-infrared satellite imagery to determine ground data, crop yields, yield components, soil properties, and for detection of crop diseases. Only one study revealed the use of GIT in Pakistan viz. Nadeem et al. (1998) as they estimated spatial variability of cotton leaf curl virus in MianChannu by using surface maps.

Steinmetz et al. (1990), Ruddy and Pachepsky (2000), and Bastiaanssen and Ali (2003) present that crop yield estimation is an essential aspect of agricultural intelligent attributes. Determining income and consumption at field scale yield plays a vital role whereas at regional and global scale the cumulative yield helps to take intelligent decisions and planning policies for trading.

Pan et al. (2009) described a method by integrating QuickBirdsatellite imagery with a production efficiency model (PEM) for crop yield estimation in Zhong lianchuan, China. In the production efficiency model (PEM) model, crop yield is a function of the photosynthetic active radiation (PAR), the fraction of absorbed photosynthetically active radiation (fAPAR) and light-use efficiency (LUE). A land cover classification method based on the 0.6 m QuickBirdsatellite imagery is employed to determine class-specific light-use efficiency (LUE). The photosynthetically active radiation (fAPAR) is associated with satellite imagery based spectral vegetation indices (SVI). To estimate crop yields, LUE, fAPAR and incident PAR data are combined in this study.

Ferencz et al. (2004) presented two methods for estimating the yield of different crops in Hungary from satellite remote sensing data. In the first method, selected crop fields as reference are chosen by using Landsat Thematic Mapper (TM) for classification to get crop estimations at field level. General Yield Unified Reference Index (GYURI) was construed by using a fitted double-Gaussian curve to the National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) data for plantation period. The country-level yield data reports with NOAA AVHRR are integrated as second method. The investigated methods are inexpensive and easy for efficient yield estimations.

Bandhopadhyay et al. (2008) also described a methodology to forecast cotton production on a regional basis using the integrated approach of GITs and crop simulation model, that is, Infocrop cotton model. The Infocrop indigenous crop growth simulator model was calibrated and validated to replicate the effect of varied weather, soil, and agronomic management practices on growth, development and cotton yield according to varieties and hybrids by using a number of different field experiments results.

Thomasson et al. (2004) present the GITs capability to predict yield before harvest for better risk management and profitability of the producers. They developed an application interface connecting the Arcview GIS (Geographic Information System) with the cotton crop growth model (Gossym), which allows it to accept inputs (remote-sensing-based plant-height estimates) and provides outputs (predictive yield) on a site-specific basis. Based on this study, the use of remote sensing data for plant height estimations appears reasonable to get better Gossym's yield prediction forecasts. Toulios et al. (2003) used agro-meteorological model for early crop estimation with field verification data in Greek. The model is based on the linear relationship between the normalized difference vegetation index (NDVI) and the photosynthetically active radiation (PAR). The three years experiment results revealed that the field measurements of estimated yield could be applied with multi-temporal remote sensing data.

Estimation of crop before arrival in market

In the past, there was no method to check crops before being taken to the market; this in due course not only causes financial losses to both the farmer and producers but also to the consumer who eventually suffers from this unsustainable condition of the commodity. The scarcity of wheat in Pakistan is one example of this unstable condition. This is because after getting good production of wheat crops, they are still scarce in the market. This can be eliminated by applying GITs in agriculture to check and balance the actual crop production and arrivals in markets and industries. Subramanian (2009) showed the difference between conventional methods based crop estimation data and remote sensing based estimations. This study leads us towards the answers of authentic questions of data produced from remote sensing.

Guo et al. (2007) demonstrate in their study that agricultural information can be acquired by the combinative methodology of automatic extraction and visual interpretation accurately and speedily through GITs.

Data management

In today's technology age, data management through metadata is significant because it illustrates data expressions that define data and make users to consistently collect, index, query and publish, as well as document the content, quality, source of organization, data format, organization, spatial reference, distribution mechanism and so on (Puntodewo and Salim, 2005). GITs provide direct understanding and insight into how best we can manage agriculture data in its overall supply chain context. The RDBMS technology is useful for integrating the Geo-Spatial data with attribute data to deal with the input, output and flows in supply chain management from grower to consumer level. The Long statistical reports, manual analysis, spreadsheets are now transformed into GIS databases for easy access and effective usage through visual/spatial presentation available not only on Desktop Computers or printed formats but also on WEB portal for worldwide access.

Decision support systems

Every application of GITs in agriculture is special. Certain fundamental principles have been appended. Agriculturalists need to access huge datasets for significant analysis of required agricultural retrievals, irrigation techniques, agro-techniques, agricultural insurance, warehousing, manufacturing, and marketing logistics. Agricul-ture is considered as a new arena for GITs implement-tation; however, remote sensing has been used effect-tively for the last 70 years. The Decision Support tool is best employed in crop suitability site analysis and irriga-tion scheduling using Geo-Spatial and Geo-Temporal analysis.

Perveen et al. (2010) explored cropland suitability analysis for optimal utilization of land resources for sustainable crop production. Agricultural land management and cropping patterns require better development strategies to increase crop production with efficient use of available land resources. In Agriculture-Spatial Decision Support System (Agro-SDSS) various techniques including Multi-Criteria Evaluation through GITs give more stable and precise decisions to the decision makers in order to evaluate all factors at a common platform. This research enables local farmers to select suitable cropping patterns for suitable areas.

Pereira et al. (2009) explore GITs in taking decision concerning cotton irrigation. For high irrigation performance and to reduce water loss by controlling the access of water percolation on the ground, a proper irrigation scheduling is required. Jackson and Tilt, (1968) and Grimes et al. (1969) stated that cotton yields are low due to unnecessary water applications. The most often available studies highlight the bad impacts of water deficiency on growth and yields of cotton crop (Grimes and Yamada, 1982; Gerik et al., 1996; Pettigrew, 2004; Karam et al., 2006; Falkenberg et al., 2007; DeTar, 2008). Many studies that describe the causes of water stress are well known (for example Bruce and Shipp, 1962; Turner et al., 1986; Pettigrew, 2004). Dalton et al. (2001), Howell et al. (2004), Gibb et al. (2004), Bhattarai et al. (2006) and Dagdelen et al. (2006) studied that relationships between methods of irrigation and scheduling provide important information to improve water usage and productivity. Shreder et al. (1977), Doorenbos and Kassam (1979), Ertek and Kanber (2003) and Dagdelen et al. (2006) discussed several functions developed for improved water-yield through GITs.

Spatial analysis

Information compilation is completely location specific in GITs. Geo-referenced data at the farm scale can assist in better decision making to improve crop productivity. The significant aspect is to make use of such data to enhance agro-productivity by choosing the right crop in the right fields or by estimating the amount of inputs necessary for a crop at every stage of growth. The corporate sector, business conventions and governmental rules and regulations have more influence than ever before. A farmer now has to be up-to-date with adequate knowledge regarding farm accounting, subsidy guidelines, agricultural legislation and regulations, taxation, crop insurance to make such key profit analysis.

Jayroe et al., (2005) describe the agriculture spatial information for fertilizer and other chemical applications. The study aimed to research: (i) a correlation verification of data gathered through yield monitor and Satellite Imagery, (ii) the relationship between vegetative growth patterns and soil electrical conductivity, and (iii) a production method of the vegetation map through satellite images used for direct investigation and decisions in mid-season chemical application.

There is always the possibility of natural hazards to crops throughout the growing periods, like excessive rain, droughts, floods etc. The crop at risk can efficiently be determined through GITs. This would make the planners to plan well like; when and what should be imported to reduce instability in Supply Chain of any crop and to provide better services to the consumer.

Sharifia et al., (2008) explain agricultural crop insurance as a key supporting policy for agricultural sustainability in many developed countries because it has a propensity to decrease farmer's risk and shield them against crop failure due to hazards.

A yield model, which simulates the biomass production of crop, was developed and validated to evaluate the impacts of hazards on yield production in growing seasons. High and low resolution multi-temporal satellite data were used with the SEBAL model (Bastiaanssen and Ali 2003; Zwart and Bastiaanssen, 2007) and meteorological data on a daily basis as an important input. The collected data were analyzed and interpreted; the results show maps of potential, actual and deficit evapo-transpiration, biomass production (total dry matter related to stem, leaves, roots and grains), soil moisture and yield reduction caused by severe temperature, drought, the deficit vapor pressure for each decade in the study area to determine the crop at risk.

GITs investigation is not confined to the usage of mapping software to draw points, lines and polygons on a map. Instead, it provides the capability to draw spatial relationships and to distinguish value in each spatial relationship.

The demand and supply planning is the most critical and sensitive part of Supply Chain Management. What is the supply and demand or what are the demands and what will be the supply is a complex question for Supply Chain Manager in the absence of accurate and timely information on the product. GITs help every actor of Cotton Supply Chain by providing near real time estimate data through analysis or by defining the trade, areas of certain crop and the influencing factors.

Supply chain management system

To calculate the current and future demand of a crop, its products and to complete its analysis, crop supply chain is required in a spatial context. If agro-businesses were to employ GITs, eventual benefits would be maximizing the management of the supply chain of crops and minimizing the losses due to unclear predictions. Simpson et al., (2006) in their study developed a GITs based logistics system for cotton transportation from farm to gin through module trucks. Several advantages are identified using a GITs based logistics program in scheduling and routing module vehicles (Simpson, S. Let al., 2006).

A geographic information system (GIS) software package (ArcGIS) was utilized to route trucks along shortest distance, quickest route, or alternate roads to pick up modules in the field and gin area. For this purpose, cotton production, ginning facilities, highways and local roads in the state of Texas were mapped using ArcGIS. Color near infrared (NIR) aerial photos was utilized as well. The transport analyst extension in ArcGIS was used to analyze the gin service areas, transport ability at regional level, which eventually result in cost evaluation for each route.

An efficient supply network would reduce the life cycle of crops in supply chain, and thus reduce costs, improve resource management accountability and distribution. Simpson et al., (2006) practically introduce GITs in this study to improve ability to manage resources for specific delivery requirements on temporal and spatial basis. GIT has potential to network all actors of Cotton Supply Chain with respect to their trade areas and relations with each other for better management and logistics of Cotton Supply Chain.

It is significant to point out here that GeoInformation Technologies are not fully utilized in the field of cotton supply chain management until now. There are not many actors/areas of that supply chain, which benefit from this technology like transportation routing, crop yield, area estimations, and others discussed in previous sections. Full employment of GITs in an efficient supply chain management of cotton is a strong need for today's world to enhance the capability of agriculture and agribusiness.

Conclusion

After an extensive literature review, it is concluded that Geo-Information Technologies (GITs) offer a valuable range of cotton supply chain management tool. GITs analysis in spatial canvas provides the opportunity to represent visually all required supply chain information in different compatible formats. GITs help decision makers to answer agriculture supply chain management questions like:

1. What is the production of the target crop for a target year?
2. What and where is the demand and supply of that target crop?
3. Where are the markets/processing units located?
4. Where are the raw crops located?
5. What is the transportation cost (both; Money and time) from the farm to the market/Processing units?
6. What is the best route that is, the shortest and safest distance?
7. What are the alternative routes, in case of problems such as traffic congestion, hazards etc., of the selected route?
8. How long will it take to reach delivery locations (Industries)?
9. How can one track goods through the crop supply chain?
10. Which and where are the Consumers (Retailer perspective)

While comparing conventional methods, GIT is more efficient in predicting accurate and timely forecasts for crop yields. On the other hand, presenting cotton supply chain data in the form of a spreadsheet ignores the real world influence of geography on each actor in the supply chain. There is a wide range of GITs software, hardware, tools and extensions to process the large bundle of data easily. Besides these, there are a number of accessible satellite images with and without cost for crop estimations and other GITs applications. Consequently, when supply chain performances are analyzed in GITs framework, the problems are immediately visible with alternatives, such as revolving cropping patterns, spatially variable fertilizer applications, and accurate acreage and yield risk estimations, rerouting to avoid delays in transportation. Proper data help managers and decision makers to achieve their competitive precedence and increase the overall supply chain sustainability and profitability. GITs based maps are not just pictures or mere maps; they are spatially variables. Integration of the spatial data along with the attribute data helps decision makers to do “what-if analysis” and actually see the implication / impact of the result in the supply chain area. The benefits and limitations of applicability of GITs in agriculture SCM are summarized below.

Benefits

More efficient Agriculture Intelligence data creation and central validation.
GITs can play vital role in relating information from grower to consumer.
GITs can limit traders / growers to rely on intermediaries.
GITs based data generation and forecasting are vital for crop risk assessments.
Geospatial based supply and demand analysis and trade area demarcation.
Agro-decision support systems.
Transparency throughout the cotton SCM.

Limitations

Gaps and unorganized secondary data with limited availability.
Cloud free satellite data throughout the growing season.
High resolution satellite images are costly.
GITs provide a standardized environment to integrate the data for numerous cotton supply chain processes. Once spatially validated, the data can be used in many other agro-economic applications, thus adding worth to the data and the chain process overall.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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