Cropland information system in Mongolia using Remote Sensing and Geographical Information System: Case study in Tsagaannuur, Selenge aimag

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ABSTRACT

Remote sensing and geographic information system technologies have been of great use to planners in planning for efficient use of natural resources at national, regional and sub-regional levels. The role of space geo-informatics in finding new resources for agriculture development for optimally managing the already available resources in order to maximize agriculture production is recognized worldwide and is found to be highly potential. We compare estimates of sub-provincial cropland area of Tsagaannuur in Mongolia from cropland cover maps derived from remote sensing data. The objectives of this study to develop crop land information system; and monitor in the crop land cover changes in the Tsagaannuur, Selenge aimag as there is important agricultural producing area in Mongolia. In this study, maximum likelihood supervised classification methodology was applied to Landsat TM and ETM images acquired in 1989 and 2000, respectively supplemented by fieldwork and use of other existing data. A supervised classification was carried out on the six reflective bands (bands 1-5 and band 7). Cropland use change detection has shown that the cropland area decreased between 1989 and 2000 by 13.4 percent from 521377 pixels to 451724 pixels. From this, land cover and farmland maps at 1:10,000 with attribute data were prepared in this area.

Keywords: Mongolia, cropland cover change, cropland information system, remote sensing, GIS

1. Introduction

The most extensive changes in land use/land cover during the last two decades in Mongolia have been occurred in agricultural land use. Mongolia is located in the eastern central part of Asia and covers an area of 1,565,000 sq. km and between the latitudes of 41°35’N and 52°09’N and the longitude of 87°44’E and 119°56’E. Nearly 90% can be used for agricultural or pastoral pursuits, 9.6% is forest and 0.9% is covered by water. Only, a 1% of Mongolia’s land area is suitable for cultivation. Less than 1% has no effective use (Batjargal.Z., 1996). Mongolia is a landlocked country between the two big neighbors, Russian and China, and no access to the sea. The time zone is 8 hours ahead of Greenwich meantime. Administratively, Mongolia is divided into 21 aimags (provinces) and aimags are divided into soums (districts).

From 1990s, Mongolia entered a period of transition from a central-based planned economy to a market economy and all cooperatives (farming) are in deep crisis and crop
production has dropped (Figure 1). Mongolia’s transition experience since 1991 has been positive, but difficult. The negative output performance of the first half of the 1990s was centered on agriculture, industry and some mining activities (B.Erdenee et al., 2010).

![Graph showing sown area (tous.ha) over years from 1960 to 2010 for Whole Mongolia and Selenge aimag.]

**Figure 1:** Whole Mongolian cultivated areas with Selenge aimag. (NSO 1960-2010)

In the course of privatization collective and state farms were restructured and the property thereof was transferred into private ownership. Privatization of agriculture was finished by 1995-1998 years when about 50 percent of arable land was at the disposal of private farms, another 50 percent belonged to agricultural enterprises established on the basis of former state and collective farms. Since 1992, cultivated area of field crops decreased from its 1989 peak of 837,900 to 372,600 hectares in 1995, as supplies of mechanical and chemical inputs were cut off (World bank., 1995). Over the past 15 years, much attention by policy-makers in Mongolia has focused on the privatization of agricultural land. National debates discussed the pros and cons of alternative policy choices, the procedures guiding the privatization of collective and state land, and the institutions in charge of policy implementation at the local level. Local people, in turn, were busy securing a share of the agricultural land for themselves and getting their claims on particular land parcels recognized.

This focus on land privatization originated from the high political significance attributed to the return of the land to ‘the people’ in the move away from socialism. In the confusion of such a changing economy and the spatial and temporal dynamics of land cover/use that are continuously evolving, it is important for the Mongolian government to have accurate and timely information for natural resources management, land-use planning and policy development, as a monitoring and modeling land-use and environmental change and as a basis for land-use statistics. Land use land cover change,
as one of the main driving forces of environmental change, is central to sustainable
development (Lambin et al., 2000).

Agriculture still remains the most vital sector in the economy of our country. The
development of databases and the information systems relating to agricultural sector
require input from various sources, their processing and dissemination for planners,
policymakers, researchers, administration and other coordinating agencies. Integrated
rural development and micro-level planning has been for few years in the successive
Mongolian National Development Plans. Since Mongolia has different types of terrain,
resources, a climate, a socio-economic level, an administrative, etc., micro-level planning
and modeling requires a comprehensive district level spatial and non-spatial databases
and integrated information systems. Several government agencies and other non-
governmental organization are engaged in the development of databases and information
systems. The major sources of this information are the National Census (social, livestock,
ariculture, etc), remote sensing data, Administrative records, financial records,
plications, Computer networks, databases, Institutional libraries, and Information base
for agricultural experiments. This information is available in different forms like tables,
text files, databases, publications etc. Moreover, some of the information is available at
different levels like States, provinces (aimag) and districts (sum) etc. Information system
is a relation based processing system that includes storage of data of various parameters
of the object.

Effective agricultural information dissemination and advisory services to the farmers are
the backbone of any practical application of geo information technology. System encloses
information on natural resources related to land, water, forests, minerals, soils etc. and
socio-economic information such as demographic data, social graces, infrastructure etc.
The integration of these sets of data would aid the decision making process for systematic
resources utilization and also aid sustainable agricultural development goals of the
country.

Agriculture represents an important economic sector in which many decision makers are
involved including the Government. The requirements of planning and decision-making
are largely in private hands, are different for individual farmers, associations and various
government departments, institutions and researchers. Information about advanced
farming is as important for farmers as inputs such as seed, fertilizer, water and pesticides.
Such information can be made available through information “one stop shop”. The one
stop shop can be put into services at local governors where farmers can have access to
computer and can get information he requires about right type of seed and fertilizer, ideal
date of sowing or harvesting, or land leasing, land price etc. Farmer can participate in
conversation with subject specialist through chats in mother language and can get direct
information from experts on technology management (water management, fertilizer
management and pest management etc). These centers can provide early warning systems
regarding on set of pest and weather forecasting by which farmer can take decision on his
own about sowing of crops, early and late drought of field, harvesting of crops and how
to combat the pest and diseases.
Therefore, there is a need to develop a comprehensive data warehouse, after eliminating different kinds of errors so that these can be retrieved and updated in required forms. Also, there have need to develop an agricultural sector based information systems at district (sum) level. The information system should contain information related to the requirements of the farmers regarding the inputs and the outputs of the occupation. It also should have a query shell for particular pre-defined necessities and suggestions to the farmers.

The objectives of the study are; to provide a recent perspective for cropland cover changes that have taken place in the 1989 and 2000 years, to integrate visual interpretation with supervised classification using GIS and to examine the capabilities of integrating remote sensing and GIS in the study area; and to develop of operational and query-based cropland information system including both spatial and non spatial information for necessary applications in cropland areas.

2. Study area

The selected study area Tsagaannuur sum(village) is located in the Selenge aimag (district) (Figure 2) is prime cropland region and located in the Northeastern part of the Mongolia, it covers mostly forest-steppe, steppe and is rich in chernozem soil. Selenge aimag is produces 60 percent of grain of the country. The climate of the region is semi-arid and arid; and the mean annual precipitation is 250-301 mm. The main crops being grown in this region are wheat, fodder crops, potato, and some vegetables. Except for wheat, all other crops are rain fed; only small part of the area is semi irrigation.

The planting dates of wheat and fodder crops are mostly planted in from the mid of May to October period. For vegetables planting starts in the end of May and continues until the end of August and mid-September.

Almost all the crops present an important vegetative development in the June–August period. The wheat is harvested between September and early October. Vegetables are harvested gradually from late July to September.

3. Data and methodology

3.1 Satellite Data

Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+) images (with path/row132/25-27, 133/25, and 131/26-27) acquired on 1989 and 2000 and ground truth data, respectively. All satellite images were cloud free and of good quality. Landsat 7 Enhanced Thematic Mapper (ETM+) imagery and ground truth data has been used to produce the baseline interpretation of 2000 using on-screen digitizing and visual interpretation. For the 1989 visual interpretation use has been made of Landsat 5 Thematic Mapper (TM) images.
Satellite data processing and analysis operations were carried out using ENVI 4.3 and PCI GEOMATICA Image Analysis software. The satellites orbit at an altitude of 705 km and provide a 16-day. These satellites also were designed and operated to collect data over a 185-km swath.

Land cover classes are typically mapped from digital remotely sensed data through the process of a supervised digital image classification (Campbell, 1987). The overall objective of the image classification procedure is to automatically categorize all pixels in an image into land cover classes or themes (Lillesand, 1994; Campbell, 1987). The maximum likelihood classifier quantitatively evaluates both the variance and covariance of the category spectral response patterns when classifying an unknown pixel so that it is considered to be one of the most accurate classifier since it is based on statistical parameters.

Supervised classification was done using ground checkpoints of the study area. The area was classified into four main classes: cropland, bare land, water body and forest. After that we mask out only cropland area. For each year classified output, the error matrix was generated and the producer’s and users and overall accuracy were calculated.
3.2 Ground truth data

The ancillary information was used to create agriculture related database at cadastral level. We were chosen for detailed sampling each polygon, where data was obtained over the course of two years. The parcels varied in size from about 8 to 3000 hectares. In most cases, due to the size of the parcels, field data collection for a single parcel would take several days. Field data was collected at 3 different times during 2007 and 2009, spanning both the cropping seasons as well as several stages of wheat maturation, from the early growth to pre-harvest.

Creating the link between the shape file containing the parcel boundaries and the production information was undertaken in two ways: First, using Arc Catalogue a spatial database connection was created with the geographic data stored in the relational database system of the Microsoft Excel. The link created a real-time spatially referenced information system where the digital maps created in ArcINFO had access to the some historical production records. This was created for the purposes of future onsite GIS analysis. Second, the parcel based database information was also extracted as .dbf files and was than linked directly to the vector map of each polygon. Each polygon points were then registered to Geographic lat/Long (Zone-48 WGS84 using) projection and the evenly distributed. The registration was based on first-degree polynomial and nearest neighbor re-sampling techniques. The accuracy of the registration was measured using independent check grids, which were not included in the transformation. Each crop polygon was assigned a numeric code, owner’s name, location and the crop types, soil moisture, air temperature, soil temperature of the ground-visited fields were recorded as attribute information (Figure-5).

4. Results and Discussion

Supervised classification using six reflective bands of the images acquired on 1989 and on 2000, respectively was carried out using maximum likelihood classifier. Figure-3 and Figure-4 show the result of the classification. In the present study only two years are available: 1989 describing the cropland-use situation under the centralized government and 2000 in a market-oriented economy. The mid 1990s are not represented but stand for the moment in which the land was distributed to rural households and registration as private property took place.

Considering the above-described limitations of remote sensing for analysis of land-use dynamics, one could state that the present results are more likely an underestimation of change than an overestimation. If more land-use aspects and information would be integrated into the study, the area subject to change would be likely to be more extensive. Cropland use change detection has shown that the cropland area decreased between 1989 and 2000 years by 13.4 percent from 521377 pixels to 451724 pixels. A standard overall accuracy for land-use maps is set between 85 (R.Anderson et al., 1976; Ram and Kolarkar., 1993; S. Khorram, Biging, G. S., Chrisman, N. R., Congalton, R. G., Dobson, J. E., Ferguson, R. L., 1999) and 90 percent (Lins and Kleckner., 1996). In this study the
overall classification accuracy was found to be 87 percent for 1989 and 91 percent for 2000.

Figure 5 demonstrated a parcel based land information system by studying the cadastral spatial data and other land-related data in Tsagaannuur of Mongolia, and provided organizational prototype concepts and guidelines for implementing a parcel based land information system. Also it is possible to do the normal operations related zoom-in and zoom out and other such operations related to layer/image in normal image handling programs.

Figure 3: Cropland use map in Tsagaannyyr sum, Selenge aimag, Landsat TM 1989.

Figure 4: Cropland use map in Tsagaannuur sum, Selenge aimag, Landsat ETM+ 2000

The mathematical operations on attributes aids in building the query and output the display to the monitor either statistically or graphically.

Lastly the crop information is dynamic and needs updating at user level and further needs deriving spatial query and output. From this point of view, an updating facility is provided via user name and password for activating update module.
Field-scale agricultural parameters monitoring by remote sensing can meet this information need, yet the current acquisition of agricultural parameters remain in large scale and macro level. Restricted by temporal and spatial resolution, accuracy of crop and environment parameters, the operational acquisition of field scale crop and environment parameters has not been realized. Besides, the lack of effective information releasing channel also prevent the monitoring result from being applied in precise farming (S. Khorram et al., 1999; Mendoza and Etter., 2002).

Figure 5: Parcel based-cropland information system of Tsagaannuur sum, Selenge aimag,

5. Conclusion

Mongolia is an agricultural country and as such the role of agriculture within the Mongolian economy has historically been and will continue to be the predominant factor in its growth and development for many years.

The current case study on cropland information system development provides useful insight into complexity involved in the ingestion spatial information. The ultimate goal of information generation is its use in decision making. The cropland cover classification for at district level was found useful in characterizing the agricultural system in Tsagaannuur sum. Therefore the study has brought out clearly a great scope to the farmer and other agriculture related sector authorities to procure proper management policies to improve agriculture activity in the local, region and state level. Above all the output generated in the study is a key towards the formulation of a management plan at local level from the perspective of sustainable development in Mongolian Agriculture.
Computers with their capacity to store large amount of information, ability to retrieve pieces of required information and its processing dissemination on computer networks have opened vast potentialities for agricultural development. Digital agriculture is useful in many situations in developing countries. During the last 50 years, numerous changes have taken place in the major components of agriculture, both in the positive as well as in negative direction. Therefore, it is the right time to take decisions, how to increase agricultural productivity, as the developing countries have the lowest productivity for most of the food crops.

Acknowledgements

The authors wish to acknowledge all members of Local governors of Selenge aimag, for their help in the development of the mapping and monitoring study site and to collect of the ground truth data. Furthermore, the authors appreciate the comments and suggestions of anonymous reviewers who helped improve the quality of the manuscript.

6. References


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