Application of satellite image data to management plan of large-scale irrigation projects

KIYOSHI TORII, Graduate School of Agric., Kyoto Univ., Sakyo, Kyoto, Japan, torii@kais.kyoto-u.ac.jp
KIYOYUKI YAOTA , Graduate School of Agric., Kyoto Univ., Sakyo, Kyoto, Japan, duaop805@sakai.zaq.ne.jp
TAKESHI HATA, Dept. of Agric. & Envi. Eng., Kobe Univ., Kobe, Japan, hata@kobe-u.ac.jp
ABDELHADI, A.W. Agric. Research Corp., Wad Medani, Sudan、0hadi@ans.ans.kobe-u.ac.jp

Abstract

We are studying large-scale irrigation projects of 100,000 ha to 1,000,000 ha in the world with emphasis on their historical courses of development, geographical conditions, water managements, planting conditions and landuse changes. Recent advancement in GIS/remote sensing techniques has enabled us to proceed studies in this field in more details. Here, we describe the results of analysis on distribution of irrigation canals, three-dimensional shape of the irrigation area and planting conditions of agricultural products investigated last year in Gezira irrigation project, Sudan, using Landsat 7 ETM data and DEM supplied by USGS.

Key Words: Sudan, Gezira, Large irrigation project, Remote sensing technique, Landsat 7

Introduction

Sudan is the largest country in Africa with an area of 2,500,000 km^2. The population in Sudan is 32,190,000 at present of 1998 and the White Nile and the Blue Nile merge one another resulting in the largest river in Africa, the Nile, in Khartoum.

Fig. 1 Map of Sudan in Africa

A gigantic irrigation project, called Gezira Scheme, exists in the area between these rivers. In this scheme covering an area of 800,000 ha, production and processing of tobacco and food processing such as cooking oil are carried out in addition to growing of basic agricultural products, such as raw cotton, wheat, sorghum, sunflower, peanuts and sesame and it is constituting an extremely important productive area in this country

While Gezira Scheme was started as a private farm of only 2,000 feddans (1 feddan = 0.42 ha) in 1911, its area was expanded rapidly as gravity irrigation facility was prepared after completion of Sennar Dam in 1925. It was expanded to 2,100,000 feddans between 1957 and 1962 and has become 2,200,000 feddans now. The topography of the area is relatively flat with a gentle inclination from north to south and from east to west and this is producing the mechanism of gravity irrigation system (Adam et al., 2002).

Originally, the agricultural development was started in this area in order to supply raw materials of cotton, a single cash crop, to textile factories in the British Commonwealth under British rule. After independence, the policy was changed to cultivate various agricultural products instead of exclusive raw cotton cultivation (Plusquellec, 1990).

Annually, irrigated farm land extending over 1,500,000 feddans are run on a four-course crop rotation basis; 350,000 feddans for raw cotton, 400,000 feddans each for wheat and sorghum, 240,000 feddans for peanuts, 50,000 feddans for vegetables, 10,000 feddans each for feed and sunflower, and 400,000 feddans as a fallow field. The Gezira plain is located in the triangle land between the Blue and the White Nile south of Khatoum. The land holds the best conditions for water delivery systems with a general slope of 15 cm per km towards the White Nile (Plusquellec 1990).

With further advancement in dam construction, more irrigation water will be available similarly to energy increasing the annual agricultural production in Gezira area by 6-10%. This plan is being put into practice and it is designed to expand the area by 1.5 times of the present situation. Gezira Scheme is producing 60% of the agricultural production in the whole Sudan now. Effort is being made to settle nomads. In the western and southern parts in particular, settlement has been promoted by securing stable water supply by digging wells and improving social services including education.

Field survey

A set of public domain data which includes USGS GTOPO30 DEM data for the study region together with the remotely sensed satellite images of the Gezira Scheme was evaluated with filed observations made with GPS. The obtained images and spatial analysis are discussed below.

Fig. 2 The route investigated by the field survey

Fig. 2 shows the tracking record by GPS when we made a field survey in Gezira area, Sudan. It shows the traveling route from Khartoum, the capitol, to Wad Medani and survey route in the project area. The accuracy is less than 10 m.

These observation and collected data were helpful for geometric correction of satellite images.

Fig.3 shows the on-the-spot photograph of the diversion works in the canal network. Fig. 4 shows the satellite image of the spot showing an important diversion works in the complicated canal network. These results show the possibility of performing image analysis by comparing on-the-spot photographs with satellite images, which are corrected geometrically to fit the data obtained by GPS.

Spatial analysis of the level data

Tthe DEM given on a mesh of about 1 km grid supplied by USGS. This map includes the area from Arabian Peninsula to Egypt, Sudan and Kenya, etc. and the Gezira area in Sudan, which is the survey area of our laboratory, is surrounded by a small rectangle. This figure is the 3-dimensional image of the levels given in 1-km grids.

The canal network plotted from a Landsat 7 ETM+ image. As it is unconceivable that the canal surface has a big inclination, the height of each point relative to its neighbors can be obtained by providing accurate surface gradient

Fig. 5 is the contour expression obtained by integrating the data from USGS GPS and and the geometrically corrected satellite image processing it by spatial statistics. This has permitted estimation of the contour in Gezira area, Sudan, nearly in its proper shape.

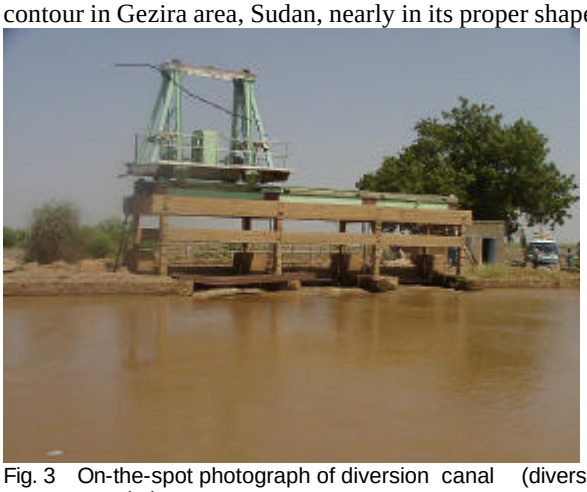

Fig. 3 On-the-spot photograph of diversion canal (diversion works)

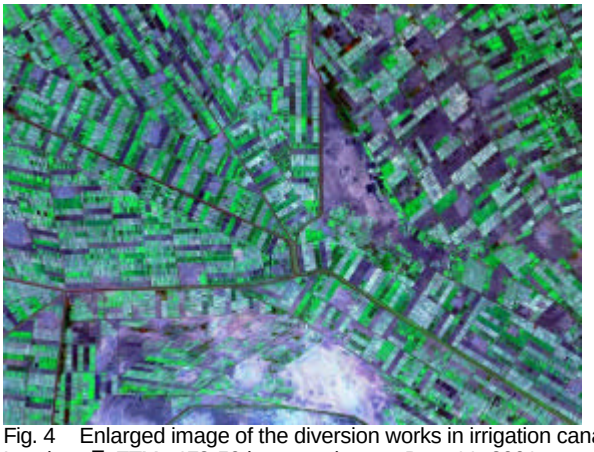

Fig. 4 Enlarged image of the diversion works in irrigation canal, Landsat 7 ETM+ 173-50 image, taken on Dec. 11, 2001

The estimated levels were 415 m near the sluice gate and 385 m at the canal end and Fig. 5 was produced giving levels to the points along the canal. Fig. 6 is the 3-dimensional expression of Fig. 5. Thus, it was possible to reproduce the topographical environment of the spot quite accurately by one field survey

Prospect for the future

Fig. 7 was prepared by overlaying the DEM data shown in Fig. 5 on the Landsat image. With Erdas Imagine utilities, a view point and a target point are provided on the image and construction of a 3-dimensional image is permitted. Fig. 8 is the bird-eye view of Sudan Gezira project area from the upper- to downstream. Due to the vast area of 1,000,000 ha in this district, it is very difficult for the administrator to collect water management data and, thus, data accumulated is scarce. Water management and agricultural product management are carried out based on long-term experiences and there seems to much waste of time.

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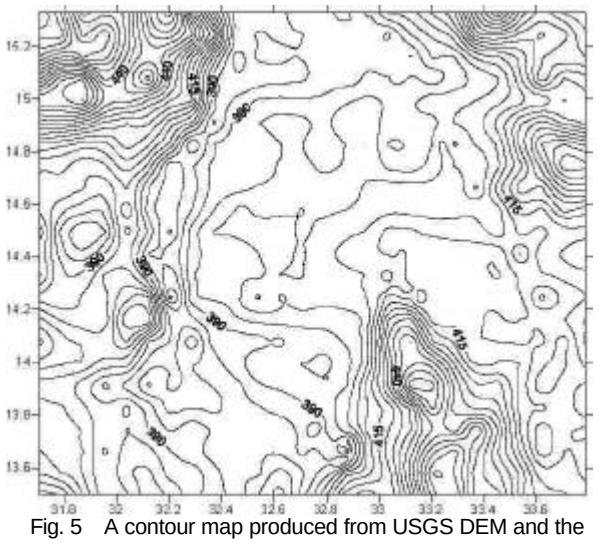

Fig. 5 A contour map produced from USGS DEM and the geometrically corrected satellite image

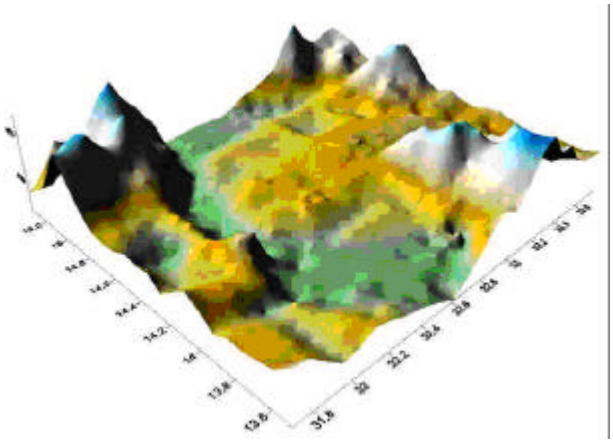
Fig. 6 3-dimensional image of the survey area estimated from GPS, satellite image and DEM of USGS

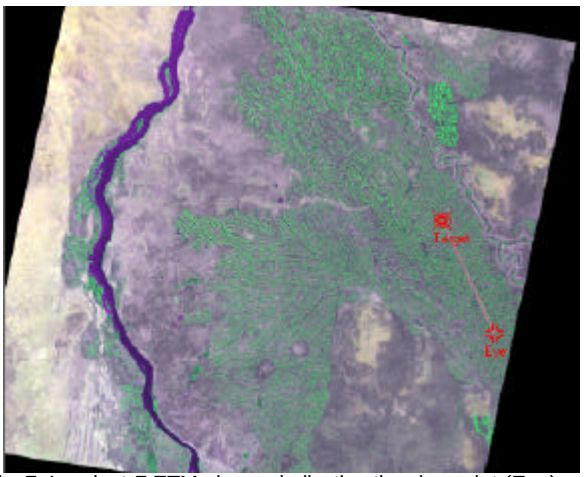
Fig. 7 Landsat-7 ETM+ image indicating the viewpoint (Eye) and the target

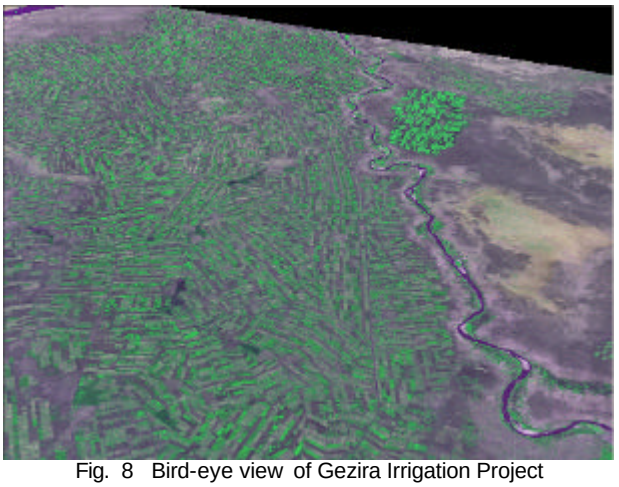
Fig. 8 Bird-eye view of Gezira Irrigation Project corresponding to the above Eye-Target line.

We are intending to perform more realistic analyses in future by overlaying these DEM data and satellite images obtained multi-temporarily. The study will be very useful for effective utilization of water resources management of agricultural products and upgrading of land uses.

Acknowledgment

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The DEM data were downloaded from USGS homepage. Satellite images were also purchased from USGS and ERDAS Imagine and RSI software were used for their processing. We express our thanks to those concerned.

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