Case study: Land and water conservation for sustainable agriculture expansion

Central India

A fundamental requirement of dynamically developing societies is that food production keeps in equilibrium with the demand imposed by the growing population, growing incomes and fast-paced urbanisation. Boosting agricultural production depends on a wide range of different measures, such as

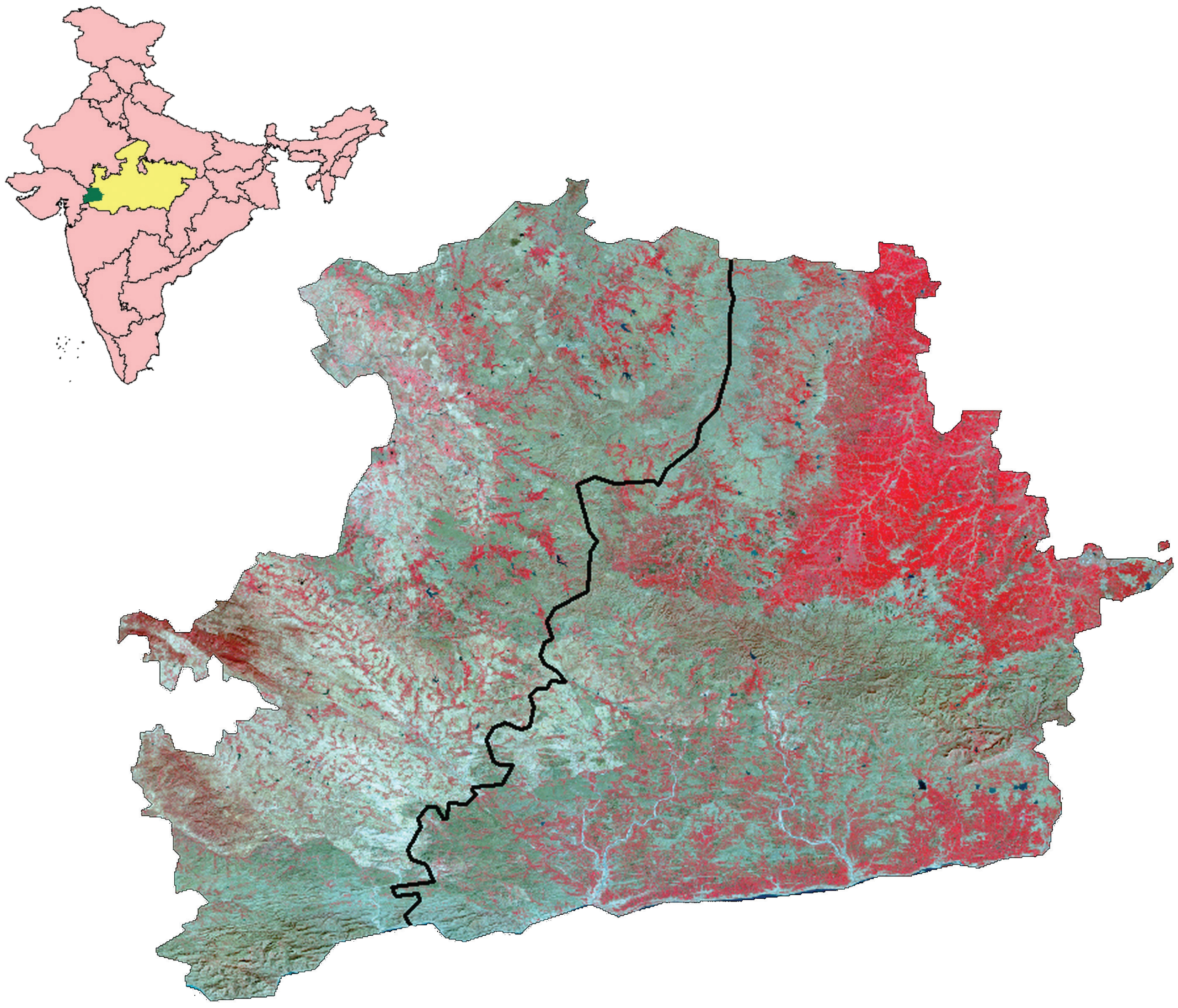
- increasing yields on existing croplands (i.e. closing yield gaps through improved crop varieties, fertiliser and pesticides, surplus irrigation in drylands, etc.) and management practices,
- expanding agricultural lands into natural ecosystems, often at the loss of critical eco-systems and biodiversity hotspots,
- re-allocating current agricultural production to more productive uses (e.g. shifting grains from animal feed to human consumable food, with vast improvements in overall system efficiency).

Each of these options has potential benefits and disadvantages, as well as significant associated challenges. The fundamental issue is whether the required gains in yields will be possible without significantly damaging other ecosystem goods and services that society is dependent on[1]. Observing trade-offs between these services is crucial, especially with respect to the risk that intensively managed agricultural lands may eventually become degraded and less productive[2].

India accounts for only 2.4 % of world's geographic area, yet supports about 16.7 % of world's human population. It has only 0.5 % of world's grazing land but supports 18 % world's cattle. 69 % of India's geographic area falls under drylands. Population growth and economic development has considerably increased the pressure on land resources, leading in many regions to land degradation and desertification.

It is estimated that approximately 32 % (105.4 million ha) of the land is subject to various processes of land degradation, such as vegetation degradation, water and wind erosion, water logging, salinisation, the impact of mining operations[3] (see map of desertification below).

Major causes of land degradation and desertification in India are deforestation, overgrazing, unsustainable land use and inadequate agricultural management practices, cultivation on marginal lands and sloping terrain, dynamic industrialisation and urbanisation and mining operations. Against the background of natural factors, such as rugged topography, climate and weather extremes, natural disasters and, last but not least, climate change effects, most of the drivers of land degradation connect to anthropogenic activities of a fast growing population.

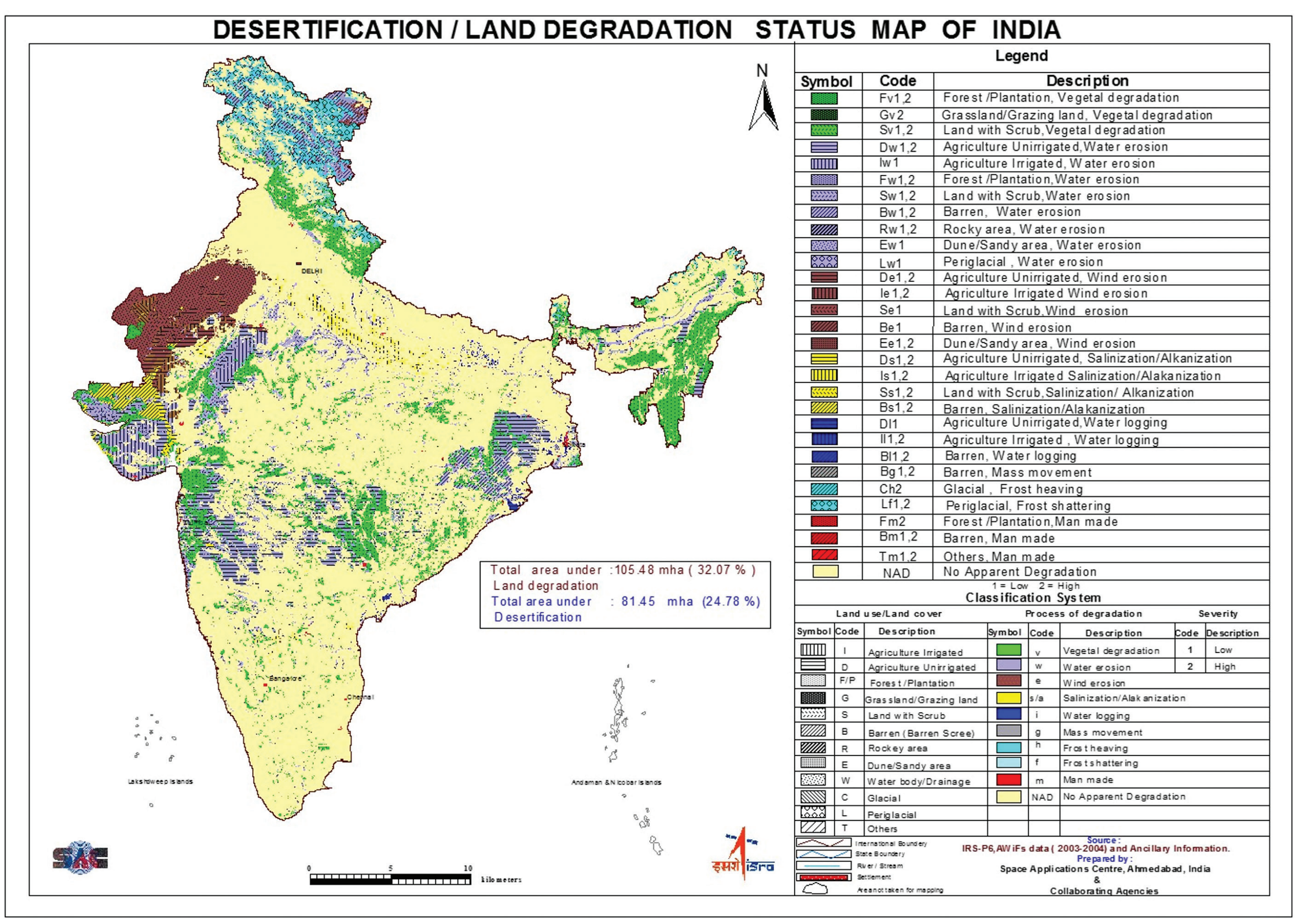


Sustainable Land Management

Slightly more than half of India's land area is used for agriculture, of which only 35 % are under irrigation. The dwindling groundwater resource of India has been of great concern in recent years. Terrestrial observations of changes in groundwater storage, together with the NASA Gravity Recovery and Climate Experiment (GRACE) satellites[4], have shown that ground-water over the Indian states of Rajasthan, Punjab and Haryana (including Delhi) was being depleted at a mean rate of $4.0 \pm 1.0\,cm\,yr^{-1}$ between 2002 and 2008[5] (see maps on next page and 'Groundwater changes' page 94). As part of watershed development programs, sustainable land management practices (SLM) have been implemented to combat land degradation, desertification and drought (LDD). Such practices aim at preserving and improving land and water resources, as well as to upgrade the ecological and environmental conditions. Improving the availability of water is a fundamental prerequisite to expand agricultural productivity and to enhance food security. The districts of Jhabua and Dhar in the state of Madhya Pradesh in central India represent an outstanding example of the positive impact of SLM implementation on combating desertification. (see satellite image above)

The Jhabua and Dhar districts in the state of Madhya Pradesh are located in central India. The districts have human population of about 1.75 and 2.2 million (2011 census) respectively, of which more than 60 % are organised in tribal structures. The main livelihood of these tribal people stems from agriculture. The two adjoining districts, with a total area of about 1.4 million ha, are located in the dry sub-humid agro-climatic zone with an average annual rainfall of about 850 mm. Both, Jhabua and Dhar districts are prone to drought and thus covered by the "Drought Prone Area Program" (DPAP) of the government. Land degradation processes cause substantial problems which affect the life of the people. Under DPAP the integrated watershed management approach primarily features soil and moisture conservation measures.

In the frame of combating land degradation, desertification and drought (LDD), a suite of appropriate sustainable land management (SLM) practices have been implemented in these districts over more than two decades. The actions focus on different kinds of soil and moisture conservation strategies and the construction of rainwater harvesting structures, with the aim to increase soil moisture storage, reduce runoff and subsequent erosion, improve ground water recharge and establish new water reservoirs for domestic use and as backup for the expansion and intensification of agriculture.



Desertification/Land Degradation status map of India.
Source: Ajai.

Central India (cont'd)

SLM: the Space Component

India promotes the operational use of Earth Observation (EO) satellite data for inventorying and monitoring the environment and natural resources, as well as for mitigating natural disasters. The country has launched a series of EO satellites, named IRS (Indian Remote Sensing Satellites). Data from the IRS series of satellites are routinely used for mapping, monitoring and management of agriculture, forests, wastelands, water resources, land use and land cover change, land degradation and desertification monitoring, watershed development, coastal and marine resources and more.

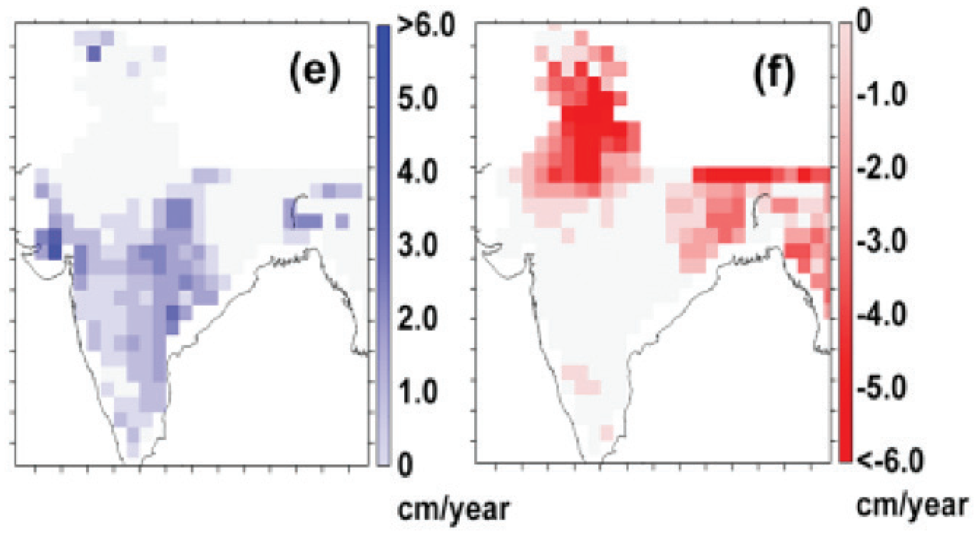
The Gravity Recovery and Climate Experiment (GRACE) twin satellites launched in March 2002, are making detailed measurements of Earth's gravity field which lead to discoveries about gravity and, indirectly, ground water storage volumes. Continued observations of groundwater trends across India (2003–2014) using data from the GRACE satellites have revealed surprising trends[6].

In contrary to the well-documented Indian groundwater depletion due to rapid and unmanaged groundwater withdrawal, regional-scale groundwater storage (GWS) replenishment is reported for the first time. The analysis used long-term in situ (1996–2014, using more than 19000 observation locations) and decadal (2003–2014) satellite-based groundwater storage measurements. In parts of western and southern India, in situ ground water storage (GWS) has been decreasing at the rate of -5.81 ± 0.38 km^3 /year (in 1996–2001) and -0.92 ± 0.12 km^3/year (in 1996–2002), but reversed to replenish at the rate of 2.04 ± 0.20 km^3/year (in 2002–2014) and 0.76 ± 0.08 km^3/year (in 2003–2014), respectively[6]. It appears that the paradigm shift in Indian groundwater withdrawal and management policies for sustainable water utilisation has started replenishing the aquifers in western and southern parts of India (see maps below).

Implementing SLM measures in the Jhabua and Dhar districts has made it possible to extend the agricultural area from 13 370 ha (1998) to 15 700 ha in 2013. Within the same period, the number of water ponds has been increased from 210 to 270.

The evolution shown on the two satellite images from 1998 and 2013 (top) demonstrate the positive effects of the sustainable land management (SLM) practices (seen in 2013 image). Surface water bodies created through construction of water harvesting structures (W), presence of water in the seasonal river through construction of a series of back-to –back check dams (D), are clearly seen on the satellite image of 2013 (see zooms of the 2013 satellite images - on the right and bottom). It is also evident that areas under agricultural use (A) could be substantially expanded in the consequence of the successful implementation of soil and moisture conservation measures (see satellite image zooms (middle next page) sowing more detail on agricultural expansion between 1998 and 2013).

Improved irrigation agriculture.



Maps of trends of (e) positive (blue), and (f) negative (red) satellite-derived ground water storage anomalies, respectively (from [6]).

New water reserve and cattle drinking pond.

Drainage line treatment.

Contour trenching and nalabunding.

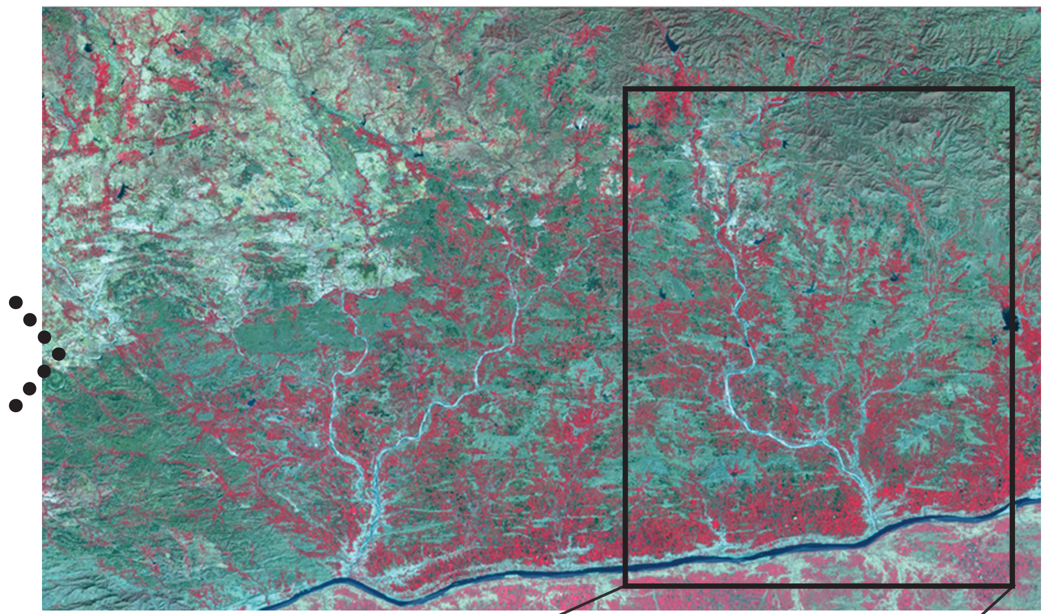
Stop dam.

Farm pond.

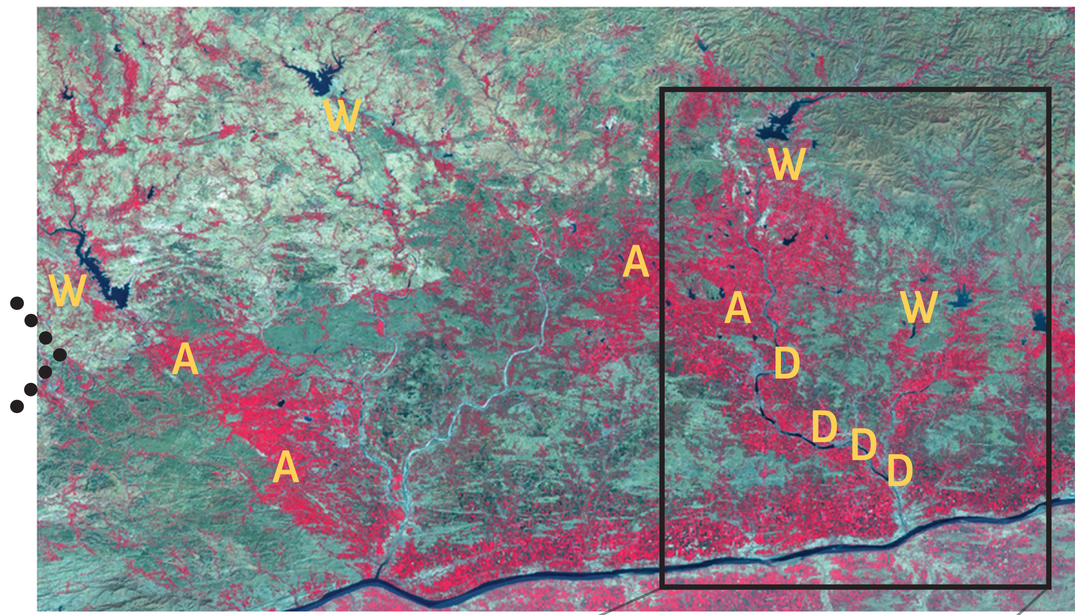
Sustainable land management practices include various kinds of soil and moisture conservation measures and the construction of rainwater harvesting structures to create surface water bodies for irrigation and domestic use. The soil and water preserving measures include contour bunding and trenching, gully plugging/nala bunds, farm bunds and others. Rainwater harvesting is supported by the construction of check/stop dams, nala bunds, farm ponds etc.

Source: Ajai.

1998



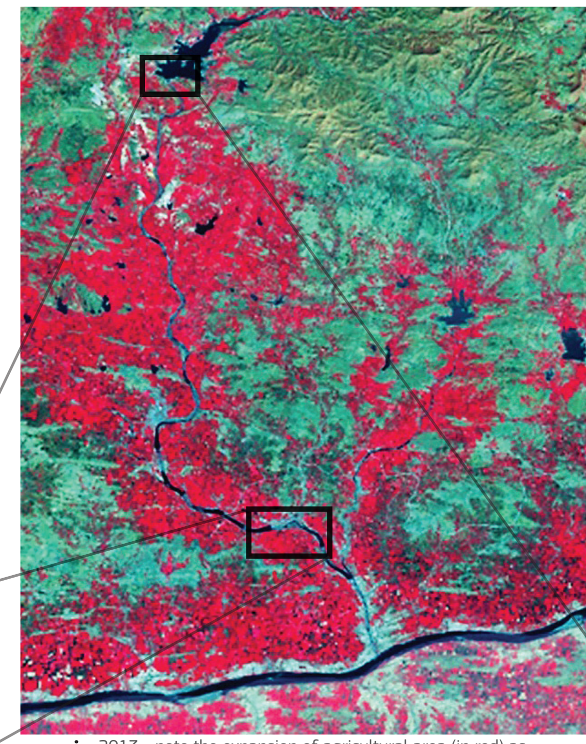
2013



IRS LISS-III false color composites of the Jhabua and Dhar districts from February 1998 (left) and February 2013 (right).

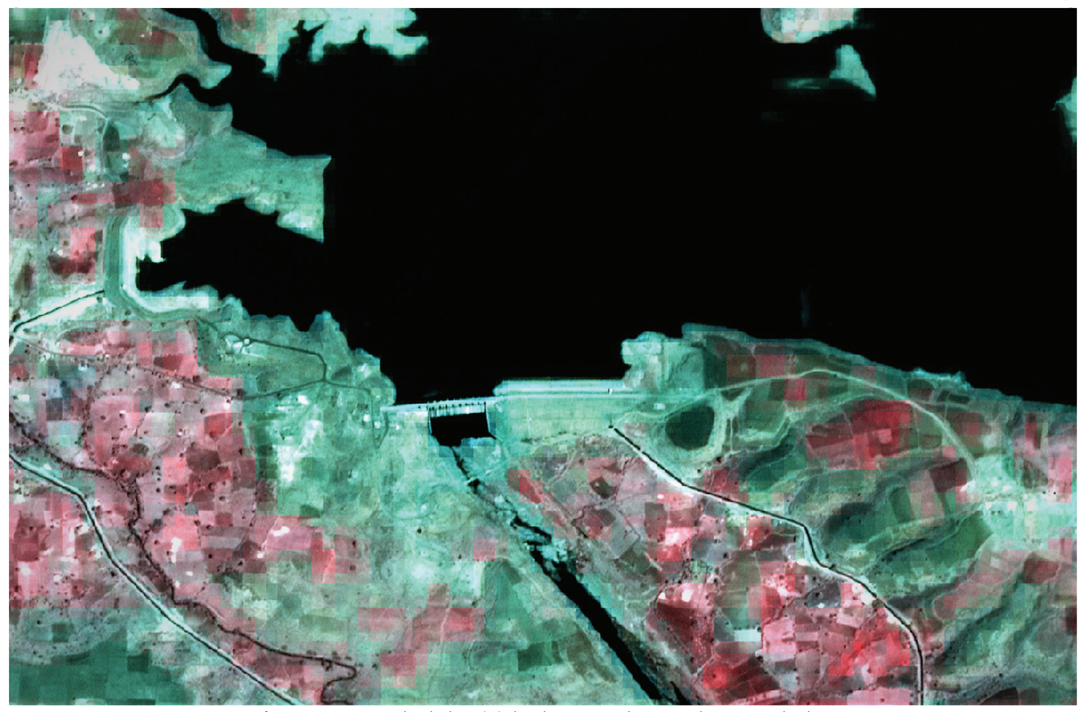
Source: IRS satellite imagery.

1998 – red colour indicates mostly agricultural fields.



2013 – note the expansion of agricultural area (in red) as compared to the 1998 situation (left).

Zoom-in on a check dam (D) that has created a water-harvesting body.



Zoom-in on a check dam (D) that has created a water-harvesting body.