Ecological Indicators 41 (2014) 96–108

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Short Communication

Auditing reforested watersheds on the loess plateau: Fangshan Shanxi

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ARTICLE INFO

Article history:
Received 18 June 2013
Received in revised form 8 January 2014
Accepted 13 January 2014

Keywords:
Rangelands
Habitats
Regoliths
Aquifers
Ecostructures
Desertification

ABSTRACT

Mapping watershed ecosystems, evaluating their ecological status and modelling land use futures are the aims of a project undertaken by an interdisciplinary team from Shanxi Forestry Academy and Watershed Systems Living Water Foundation. The project introduces geospatial methodologies and iGiS technologies for (a) mapping and modelling watersheds and (b) monitoring and evaluating rangeland restoration after reassigning collective forest lands to local farmers in accordance with land reform policies.

Two contemporary geospatial technologies were instrumental in the Fangshan project. These technologies are driving a paradigm shift in the way primary industries like mining, farming and forestry utilize GIS, engage in land evaluations, resource mapping, environmental assessments and product certification.

- Firstly, high resolution, true image 3D orthophoto mapping was produced as the iGiS map platform for the Fangshan project. The true colour orthophoto maps produced by the team proved very suitable, with the high resolution imagery achieving cartographic standards allowing draft mapping at 1:2000. Because unique *x*,*y*,*z* geocentroid coordinates are generated for each and every pixel in the orthophoto mapping process, detailed iGiS data bases with multiple attributes ranked parametrically were readily captured and recorded for every habitat and regolith.
- Secondly, the Shanxi Forest Academy team were trained in geospatial methodologies for mapping watershed ecosystems and modelling their habitat/regolith/energy relationships. Using GiS imaging technologies, these cartographic simulation methodologies enable ecological modelling of watersheds and their subterranean water systems, while providing a framework for monitoring and evaluating the environmental health of watersheds using permanent benchmarks and ecological indicators.

Habitat mapping and modelling of Fangshan watersheds revealed how ecological restoration is gradually occurring through strategic combinations of planned reforestation, traditional terrace farming systems and natural regeneration. These ecological strategies are shown to be beneficial land use partners in restoring the mountain rangelands, riparian ecostructures and ecosystem functions of degraded loess plateau watersheds.

1. Introduction

This paper outlines a heuristic method for auditing the ecological performance of rangeland watersheds and river floodplains using digital imagery and geographic information technologies. Trialled and tested successfully in trans-disciplinary R&D projects in Australia, New Zealand, India and China, geospatial toolkits combine well with heuristic research methods to generate unexpected research outcomes, while providing ecological indicators for evaluating the performance of watersheds. They are now ready to be introduced to a wider audience.

Increasingly in the modern world, digital imaging systems are preferred tools for medical, mining, environmental health and watershed R&D (Hall, 1992; Goodchild, 1996). Instead of reliance on statistical samples and topographic maps, up-to-date, true orthophoto imagery provides complete 3D coverage of the watershed in fine detail. This provides the GiS platform enabling accurate mapping and geospatial modelling. A case study of reforested rangelands in Fangshan County outlines how these new geospatial tools can be used in watershed R&D projects.

Since the 1990s, digital methods for mapping habitats and modelling watersheds have been added to the toolbox of professional practitioners in fields such as land evaluation, land use planning and watershed ecology. This paper is not a detailed review of these

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http://dx.doi.org/10.1016/j.ecolind.2014.01.016

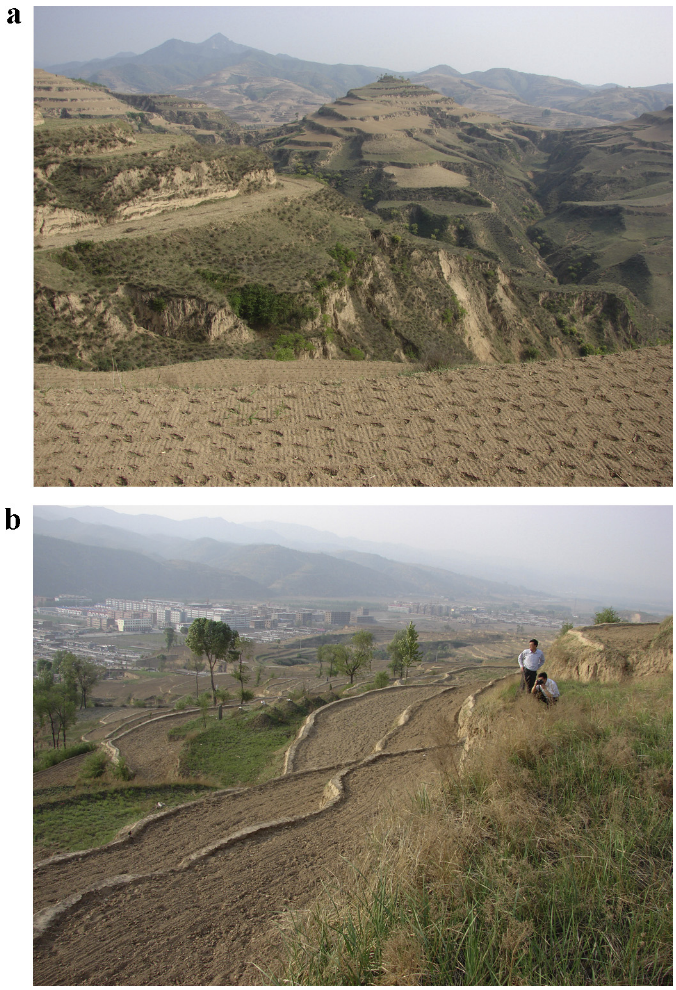

Fig. 1. Fangshan study area (photos Haikai Tane).

digital mapping methods. The objective is to show how to map watershed habitats and model spatial relationships with groundwater aquifers and atmospheric energy systems; to reveal the ecological status of watersheds.

1.1. Study area

In 2010, watershed audits of reforested rangelands in Fangshan County (111° E 38° N) began with field training programs at Shanxi Forestry Academy. By the end of 2012, habitat and regolith mapping were completed for partially reforested watersheds totalling 200 ha. Subsequently, indicators of atmospheric energies powering watershed ecosystems were developed and loaded in the Fangshan iGiS. Together, these ecological indicators enabled assessments of progress with restoration of rangeland watersheds on the loess plateau.

The Fangshan study area is shown in Fig. 1 with two perspectives of typical loess rangeland watersheds. The watersheds are located 1000 ± 100 m above sea level between the Yellow River Valley and Guandi Shan (2831 m). Fangshan County is a rural locality characterised by deep dissected loess hills, eroded mountains and narrow stream valleys. It is a settled area with an intricate patchwork of steep reforested gullies with terrace farmlands on rolling hills and valleys. Severe desertification is long standing and entrenched.

1.2. Paradigm shift in mapping watersheds

Until the 1990s, the most readily available maps were paper topographic maps with a two dimension matrix of Easting/Northing references representing latitudes and longitudes. Contour isopleths provided a surrogate measure of altitude. Land features were added using a range of cartographic icons and symbols. By and large, spot locations were relative, contours had low positional accuracy, site symbols were confusing and land resource assessments were overly subjective. This rendered the maps and spatial information derived from them, rather unreliable and less than useful for most researchers. Few people could read and understand these analogue paper maps or their "spaghetti" logic. Cartographic training and experience were necessary to read them (River Murray Mapping Task Force, 1995).

All this began changing in 1992 with the introduction of digital image mapping and global geocentroid (*x*,*y*,*z*) coordinates for global mapping and world navigation systems. By Year 2000, up-to-date, orthophoto maps with accurate digital terrain models (DTMs) were widely available. In many countries they are routinely used by farmers, foresters and mining corporations for mapping, modelling and monitoring their activities (River Murray Mapping Task Force, 1995). Producing true image 3D orthophoto mapping, at the desired scale and accuracy for auditing watersheds, requires image processing, spherical trigonometry, digital photogrammetry and geocentroid datum. Like driving a motor car, it is not necessary to be able to build the vehicle. Orthophoto mapping can be purchased over the internet at the required scale, accuracy and resolution, or constructed by cartographers with photogrammetry capabilities.

In digital orthophoto mapping, each pixel underpinning raster image maps has a unique *x*,*y*,*z* identity, allowing site specific data to be assigned to each polygon and pixel. Fangshan orthophotos are true image maps based on Shanxi's surveyed 10 m DTM, making them more reliable and more easily understood than topographic maps at 1:10,000. Orthophoto maps are free of highly variable distortions that make aerial photos unreliable for mapping watersheds or evaluating their performance.

2. Methods of modelling river basins

There are two paradigms commonly used for mapping and modelling river floodplains and their river basins. For present purposes, it is sufficient to note the engineering "catchment drainage" paradigm has dominated Western science since Roman times (2000 ± Years BP). By comparison, the ecographic "watershed storage" paradigm has dominated Eastern and Oceanic cultures for at least 5000 years (Bardon, 1991; Tane, 1996). It is sometimes mistakenly assumed the two terms have similar meanings, resulting in cognitive dissonance and disputes. To avoid this problem, a glossary of technical terms and acronyms is provided in Appendix 1.

2.1. Catchments or watersheds?

The English word "catchment" originated as a technical engineering term for the surface drainage area of storm waters or sewage effluents. Since the 1950s, it has been extended to river, school and market catchments. In the catchment model, river basins are represented as closed confined surfaces draining water away. Land capability units provide spatial units for land evaluation. Land capability units are theoretical entities assumed to be spatially homogeneous. They are classified by grouping land areas with similar attributes and limitations in generic land capability classes. This approach was relatively common until the introduction of true image mapping, computer simulation and iGiS methodologies (River Murray Mapping Task Force, 1995).