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Vegetation Analysis in Radhanagari Tehsil (Kolhapur, Maharashtra, India) Using Landsat 8 Spectral Indices: A Geoinformatics Approach

V. S. Pawar-Patil

Abstract

Vegetation cover underpins ecological balance, soil protection and water regulation, and in the Western Ghats its condition is a key indicator of land-management needs. This study evaluates the spatial condition of vegetation in Radhanagari tehsil (907 km²), Kolhapur district, Maharashtra, India, using Landsat 8 Operational Land Imager (OLI) data. Atmospherically corrected bands were processed in ERDAS Imagine and QGIS, and four spectral indices were derived: the Normalised Ratio Vegetation Index (NRVI), Normalised Difference Vegetation Index (NDVI), Atmospherically Resistant Vegetation Index (ARVI) and Soil-Adjusted Vegetation Index (SAVI). The indices ranged from −0.173 to 0.518 (NRVI), −0.434 to 0.774 (NDVI), −0.076 to 0.372 (ARVI) and −0.260 to 0.777 (SAVI). All four indices consistently placed the densest and most vigorous vegetation in the south-western and western parts of the tehsil, where semi-deciduous and semi-evergreen forest occurs on the Western Ghats flank, and a secondary zone of good vegetation along irrigated lower river reaches. In contrast, the central hill spurs that form the water divides and the north-eastern part of the tehsil returned low index values, indicating sparse cover and vegetation stress. These areas are priorities for afforestation, agroforestry and social forestry. The findings give a spatially explicit baseline for forest management in the region, and they should be strengthened by multi-date imagery and field validation.

Keywords: *Vegetation indices; Landsat 8 OLI; NDVI; SAVI; ARVI; Western Ghats; Afforestation; Geoinformatics*

Introduction

Vegetation regulates the energy, water and carbon exchange between land and atmosphere, protects soil from erosion and supports biodiversity. Forest policy in India has long aimed at keeping about one-third of the land area under tree cover for ecological stability, but agricultural expansion, commercial wood extraction, built-up growth, quarrying and grazing continue to erode vegetated land across the tropics (Hansen et al., 2013). The Western Ghats, a global biodiversity hotspot, are especially exposed to these pressures (Myers et al., 2000), so periodic, spatially explicit assessment of vegetation condition is needed for sound forest management.

Satellite remote sensing provides a repeatable and economical way to describe vegetation growth, vigour and distribution over large areas. Vegetation indices (VIs) combine reflectance in the red and near-infrared (NIR) wavelengths, where healthy foliage absorbs and scatters radiation very differently, to produce a single measure of greenness that correlates with leaf area, biomass and photosynthetic activity (Tucker, 1979; Myneni et al., 1995; Bannari et al., 1995). They have been used to monitor ecological responses to environmental change (Pettorelli et al., 2005), to support precision agriculture (Mulla, 2013) and to track forest cover, and recent reviews document how many indices have been developed and applied (Xue & Su, 2017).

No single index is free of limitations. The ratio and normalised-difference indices are sensitive to soil background, atmospheric scattering and illumination, which prompted the development of soil-adjusted and atmospherically resistant variants (Huete, 1988; Kaufman & Tanré, 1992; Liu & Huete, 1995; Huete et al., 2002). Comparing several indices over the same area therefore gives a more robust picture than relying on one. Landsat 8 OLI, with its 30 m multispectral bands and improved radiometric quality, is well suited to such work (Roy et al., 2014).

Radhanagari tehsil, on the eastern flank of the Western Ghats in Kolhapur district, combines forested hills, high rainfall and several water-resource projects, yet its vegetation has not been described with a multi-index, geoinformatics approach. This study therefore (i) computes NRVI, NDVI, ARVI and SAVI from Landsat 8 OLI data; (ii) maps and compares the spatial pattern of vegetation condition they reveal; and (iii) identifies areas of vegetation stress that merit afforestation and related interventions.

Study area

Radhanagari tehsil lies in the western part of Kolhapur district, on the eastern flank of the Western Ghats, between approximately 16°12′–16°37′ N and 73°52′–74°13′ E (Fig. 1). It covers 907 km^2, comprises 114 villages and has a reported population of 188,107. The terrain is hilly and rugged, with high rainfall, and the spurs of the Western Ghats running from the south-west to the north-east form the local water divides. Despite this relief, the tehsil has a number of major and minor water-resource projects, and green forest is concentrated in its south-western part and on the Ghats off-shoots.

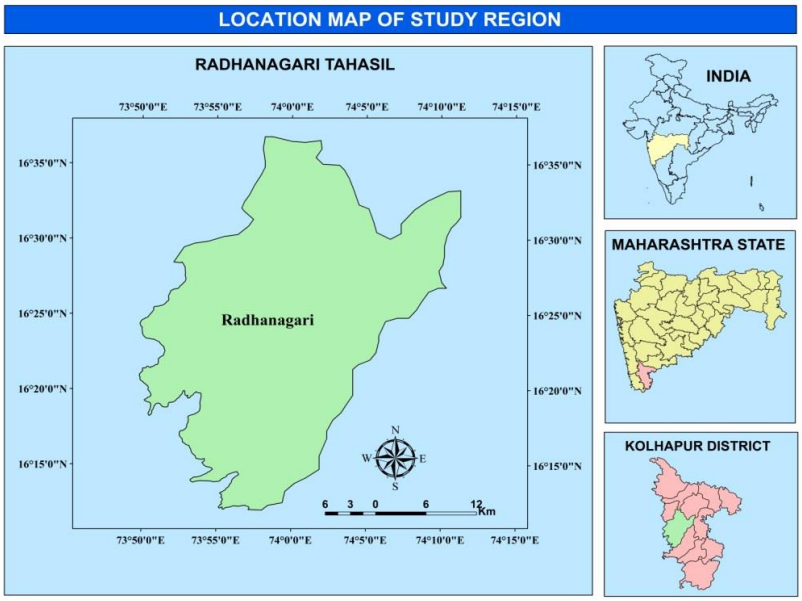


Fig. 1. Location of Radhanagari tehsil in Kolhapur district, Maharashtra, India.

Data and methods

1 Satellite data and pre-processing

Landsat 8 OLI imagery covering the tehsil was downloaded from the United States Geological Survey (USGS) EarthExplorer portal (scene identifier and acquisition date: [to be inserted by the author]). The data were imported into ERDAS Imagine, where they were converted to top-of-atmosphere reflectance following the standard radiometric rescaling coefficients supplied with the product (cf. Chander et al., 2009), and all bands were clipped to the tehsil boundary. The clipped blue (band 2), red (band 4) and NIR (band 5) layers were then imported into QGIS, and the indices were computed with the raster calculator.

2 Vegetation indices

Four indices were derived (Table 1). The Normalised Ratio Vegetation Index (NRVI) is a normalised transformation of the simple ratio of red to NIR reflectance introduced by Jordan (1969), and it was designed to stabilise the variance of the ratio (Baret & Guyot, 1991). The NDVI (Rouse et al., 1974) is the normalised difference of NIR and red reflectance:

$$\mathrm{NDVI} = (\mathrm{NIR} - \mathrm{Red}) / (\mathrm{NIR} + \mathrm{Red}) \quad (1)$$

and ranges from −1 to +1. Kaufman and Tanré (1992) added the blue band to correct for aerosol effects on the red band, giving the ARVI:

$$\mathrm{ARVI} = (\mathrm{NIR} - \mathrm{RB}) / (\mathrm{NIR} + \mathrm{RB}), \quad \mathrm{RB} = \mathrm{Red} - \gamma\,(\mathrm{Blue} - \mathrm{Red}) \quad (2)$$

where γ is a calibration constant, commonly set to 1. The SAVI (Huete, 1988) introduces a soil-adjustment factor L to reduce the influence of background soil brightness:

$$\mathrm{SAVI} = [(\mathrm{NIR} - \mathrm{Red}) / (\mathrm{NIR} + \mathrm{Red} + L)]\,(1 + L) \quad (3)$$

The value of L is normally close to 0.5 for intermediate vegetation density; when $L = 0$ the SAVI reduces to the NDVI, and the index is theoretically bounded by −1 and +1. In this study, $L = 0.5$ and $\gamma = 1$ were used

Table 1. Vegetation indices used in the study.

Index	Principle	Reference
NRVI	Normalised form of the red/NIR ratio	Jordan (1969); Baret & Guyot (1991)
NDVI	Normalised NIR–red difference	Rouse et al. (1974)
ARVI	Blue-band correction for atmospheric effects	Kaufman & Tanré (1992)
SAVI	Soil-brightness adjustment factor L	Huete (1988)

Source: Compiled by the author.

3 Mapping and interpretation

Each index was displayed as a continuous colour ramp from low (red) to high (green) values, and the NDVI was additionally classified into six classes. Spatial patterns were interpreted visually against the physiography of the tehsil,

namely the Ghats flank, the central water-divide spurs, the reservoirs and the lower river reaches. Water bodies were identified from their negative index values and are excluded from the vegetation interpretation.

Results and discussion

1 Normalised Ratio Vegetation Index

The NRVI ranges from −0.173 to 0.518 (Table 2; Fig. 2a). Its highest values occupy the south-western green zone of the tehsil, which indicates good biomass condition of the vegetation there. The ratio-based indices respond strongly to dense canopies and to green biomass, but they are less reliable where plant cover is sparse and the soil and atmosphere contribute more to the signal (Jordan, 1969; Bannari et al., 1995). This caution applies to the lower values seen over the central and north-eastern parts of the tehsil.

2 Normalised Difference Vegetation Index

NDVI values range from −0.434 to 0.774 (Table 2; Fig. 2b). The highest classes (0.476–0.598 and 0.599–0.774) form a continuous belt along the western and south-western Ghats flank, which matches the distribution of evergreen, semi-evergreen and deciduous forest, whereas the intermediate and low classes (below 0.475) dominate the central and north-eastern parts. Fairly good vegetation also occurs along the lower reaches of the river basins, which is attributed to the development of irrigation. Negative values correspond to the reservoirs, which are shown separately. The NDVI is widely used because it relates well to canopy structure, leaf area and canopy photosynthesis (Gamon et al., 1995; Grace et al., 2007), but it saturates in dense canopies and is affected by soil brightness, atmosphere, cloud and shadow (Huete et al., 2002), so its highest classes should be read as dense cover and not as a precise biomass measure.

Table 2. Value range of the vegetation indices in Radhanagari tehsil.

Index	Minimum	Maximum
NRVI	−0.173	0.518
NDVI	−0.434	0.774
ARVI	−0.076	0.372
SAVI	−0.260	0.777

Source: Computed by the author from Landsat 8 OLI data.

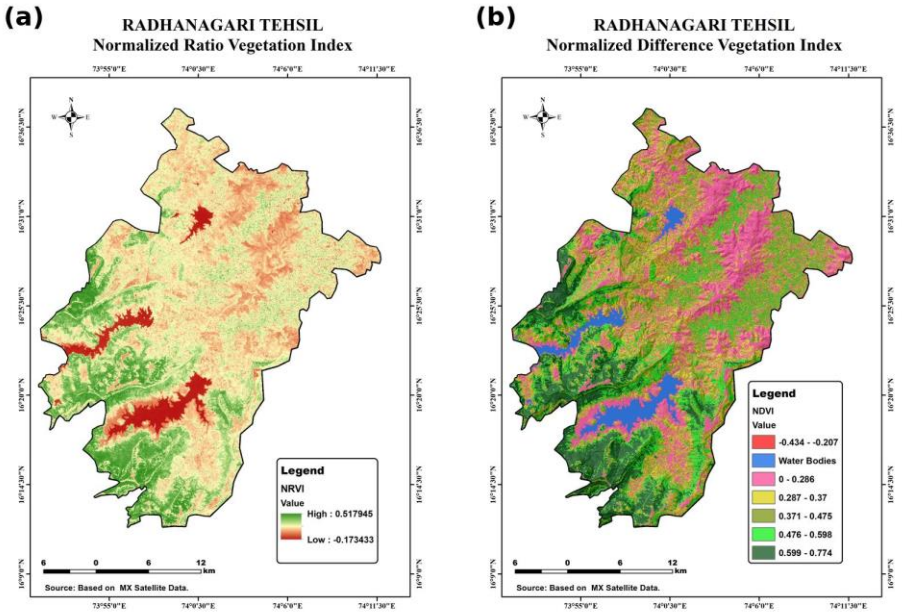


Fig. 2. (a) Normalised Ratio Vegetation Index (NRVI) and (b) Normalised Difference Vegetation Index (NDVI) of Radhanagari tehsil.

3 Atmospherically Resistant Vegetation Index

ARVI values range from −0.076 to 0.372 (Fig. 3a). Because the blue-band correction reduces dependence on atmospheric aerosols, ARVI offers a check on whether the NDVI pattern is an atmospheric artefact (Kaufman & Tanré, 1992). The highest values again lie in the densely vegetated western and south-western parts of the tehsil, which supports the NDVI result. The narrower ARVI range reflects the way the blue-band correction compresses the index relative to NDVI. Residual aerosol and ozone effects still require explicit atmospheric modelling such as the 5S code (Tanré et al., 1990).

4 Soil-Adjusted Vegetation Index

SAVI ranges from −0.260 to 0.777 (Fig. 3b). The fairly dense vegetation on the Western Ghats hills of the south-west shows good condition, whereas the water divides in the central and north-eastern parts have low SAVI values that suggest dry conditions and a low degree of vegetation cover. Because the soil-adjustment factor suppresses background soil effects (Huete, 1988), the low SAVI over the central and north-eastern spurs is unlikely to be caused solely by bright soil, and it points to genuinely sparse vegetation.

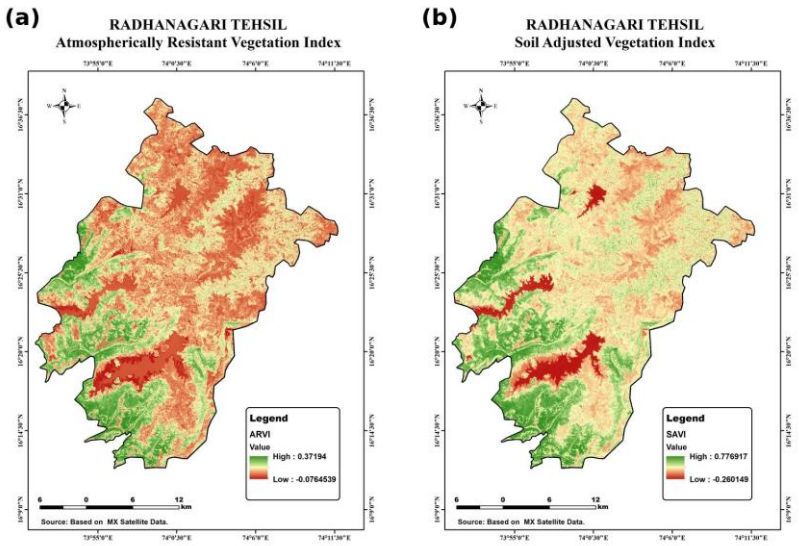


Fig. 3. (a) Atmospherically Resistant Vegetation Index (ARVI) and (b) Soil-Adjusted Vegetation Index (SAVI) of Radhanagari tehsil.

5 Integrated pattern and management implications

The four indices agree on the main spatial pattern. Dense to moderately dense canopy, with high chlorophyll activity, covers the western and south-western parts of the tehsil, where evergreen, semi-evergreen and deciduous forests are found. A secondary zone of good vegetation follows the irrigated lower river reaches. By contrast, the middle hill spurs that traverse the tehsil from the south-west to the north-east, and the north-eastern part, return consistently low values, which indicates stressed vegetation on steep, undulating, partly barren slopes. These are the areas where afforestation is most needed. Agroforestry and social forestry would both restore tree cover and provide fuel, fodder and income, and they would help reduce runoff and soil loss on slopes that receive heavy monsoon rain.

Several limitations apply. The assessment relies on a single scene, so seasonal phenology, and in particular the difference between deciduous leaf-off and true vegetation loss, cannot be separated. Steep terrain produces illumination effects that can alter index values (Matsushita et al., 2007), the 30 m pixels mix cover types, and no field data were available to calibrate or validate the classes. Multi-date imagery, topographic correction and ground-truth plots would make future assessments more robust.

Conclusions

Using Landsat 8 OLI data, four vegetation indices (NRVI, NDVI, ARVI and SAVI) were computed and mapped for Radhanagari tehsil. All of them show that the best vegetation condition, with dense to moderately dense canopy and high chlorophyll content, lies in the western and south-western parts of the tehsil on the Western Ghats flank, and that irrigated lower river reaches also support fairly good cover. Low index values over the middle hill spurs and the north-eastern part indicate stressed, sparse vegetation. Afforestation through agroforestry and social forestry is recommended there to improve cover and biodiversity. The index maps provide a baseline for forest planning, and the work should next be extended with multi-temporal imagery, field validation and quantification of class areas.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of thesis paper.

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