

SOCIOECONOMIC DRIVERS OF LAND USE INTENSIFICATION IN FIJI ISLANDS: A GEOGRAPHICAL APPROACH

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ABSTRACT

Shifting cultivation is a common agricultural practice in the Pacific Islands rarely sustainable today since fallow periods are ever shorter due to the demographic growth, farms fragmentation, uncertain land tenure, and pressures from the market economy among other factors (drivers). Official statistical data and maps were utilized to build up choropleth maps indicating the areas of high land use intensity (LUI) according to farm size ranges and socioeconomic parameters (treatments) for the country. Twenty vector layers were digitized from published maps for eight ranges of farm sizes (from less than 1 to more than 100ha), and converted to raster format with a 170m² pixel size. Critical maps were then built by boolean operations displaying areas in which both the land use and the socioeconomic driver were simultaneously ranked as high or very high. Treatments showed significant differences among them ($p < 0.05$), being the most influential those related to human demography. In farms smaller than 3ha land use is intense when (in order of importance) Indo-fijian population, household size and land availability values are high; while in farms of 20-50ha size it is intense when the values of (in order of importance) population change, Indo-fijian population, land availability, fishing and sugar farming are also high. LUI patterns normally decrease with the increase of farm size, but increases on farms over 20ha size. It is recommended to propose policies that will des-accelerate the rates of land use, such as the facilitation of land ownership over farms of bigger sizes, the gradual replacement of mono cropping by agroforestry systems, and the creation of more employment opportunities in the industry, tourism and services sectors.

KEYWORDS

Land use intensification, shifting cultivation, Boolean operations, Fiji islands.

1.0 INTRODUCTION

Deforestation and forest degradation are both critical environmental problems with serious long term economic, social and ecological consequences. In many tropical countries the rates of deforestation were based on estimates or surrogate data, rather than on empirical studies (FRA 2000, Boroffice 2006); the varied and complex causes (drivers) interplay in a synergetic way (Megevand 2013). Subsistence farmers and local communities are the most relevant agents of deforestation in the ways they respond to external pressures and incentives (Hoffmanna et al 2018) depending on the region (Mas and Cueva 2015). Shifting cultivation is still an extensive strategy in Oceania (Roos et al. 2016) in which relatively short periods of continuous cultivation are followed by relatively long periods of fallow (FAO 1982). Short fallows trigger yield declines (Kafle 2011). After shifting cultivation both the fallow age and land use intensity influence the recovery of native trees diversity (Mukul 2015); the forest degradation and subsequent rural poverty worsens in a cycle when there are few economic alternatives, unstable or low market prices, no incentives for innovation, and successive subdivision of land at the death of the owner (Chayanov 1966) (figure 1).

Patterns of crop planting are determined by variations in rainfall. Mean monthly temperature ranges from 23°C in July and August to 27°C in January. The southeaster

shorelines of the big islands get 3,000 to 5,000mm per year (FMS 2015). The distribution of the major commercial crops in Fiji is not determined primarily by the physical environment, coconuts and bananas are more related to the absence of alternative cash crops, and rice farms depend on the distribution of Indian farmers rather than on the particular suitability of the soil and climate of the producing areas (Walsh and Crosbie 2006). Only 16% of the land in Fiji is used for arable farming in valleys, river deltas and coastal plains. Eighty four percent of the land is hold under customary ownership, 38% of it is leased, only 85 of the total land area is of freehold and 3.8% belongs to the State (Walsh and Crosbie 2006).

The land-use suitability analysis identifies the most appropriate spatial pattern for future land uses according to specify requirements, preferences, or predictors of some activity (Hopkins, 1977; Collins et al., 2001). Overlay analysis is a common method to understand spatial interaction from more than two pieces of spatial information (Miyazaki and Fujii 2011) in which the Boolean intersection and the Boolean union result in classifying areas as suitable for a particular land use if each suitability map meets its threshold, or at least one suitability threshold value accordingly (Malczewski 2004).

The hypotheses in this paper is firstly that there are significant differences between impacts of drivers on the intensification of land use, and secondly, that there are significant differences among the land use intensity index values at land holdings of different sizes in the country.

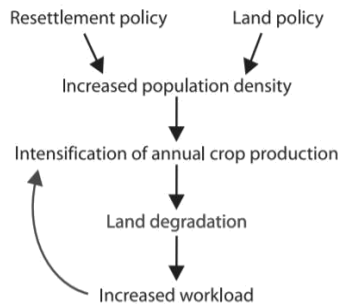


Figure 1. Policy, population and degradation cycle. With a limited amount of agricultural land available, and decreasing land yields, farmers use labour to keep land producing (IWM 2015).

2.0 MATERIALS AND METHODS

Statistical and geographical data used were maps from the Fiji Encyclopaedic Atlas produced in ArcMap (Walsh and Crosbie 2006) and the 2009 national agricultural census which include data from 1970 and 1990. Sixteen maps were selected, scanned, imported into Ilwis open (Ilwis 2020) and georeferenced with WGS84 projection and corner coordinates 15°43'31.29"S, 176°29'04.38"E (top left) and 19°28'03.47"S, 178°25'58.51"W (bottom right), with 5.6 seconds pixel size. *Tikina* (district) boundaries were digitized, converted into polygons and rasterized. Twenty vector layers were made for eight ranges of farm sizes, with a 170m² pixel size. They were re categorized into very low, low, intermediate, high and very high ranks. A land use intensity index (LUI) was calculated as $LUI = \frac{\text{Total crops area}}{\text{total crops area} + \text{fallows area}}$. Eight maps showing land use intensity per province according to farm size range (less than 1ha, 1-3ha, 3-5ha, 5-10ha, 10-20ha, 20-50ha, 50-100ha, and over 100ha) were produced. To answer the question on how are the socioeconomic drivers (maps) related to land use intensity, critical maps were built displaying areas in which both the land use and the socioeconomic driver were simultaneously ranked as high or very high, according to the following script:

Critical map = IFF ((('LUI map' = "very high") OR ('LUI map' = "high")) AND (('Land available map' = "very high") OR ('Land available map' = "high"))), "related", "unrelated").

The script ran 160 times to produce 160 critical maps, which display areas in which both the land use and the socioeconomic driver were simultaneously ranked as high or very high. Their pixel numbers were tabulated, statistically tested and interpreted.

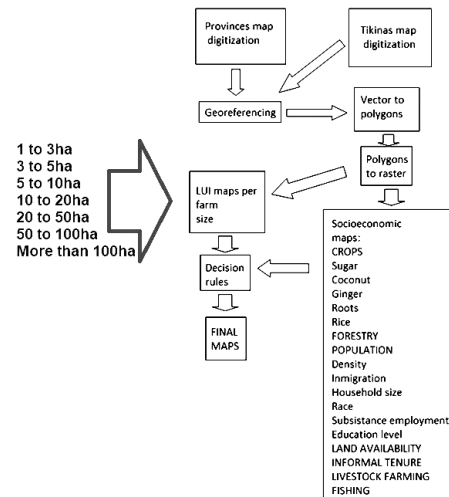
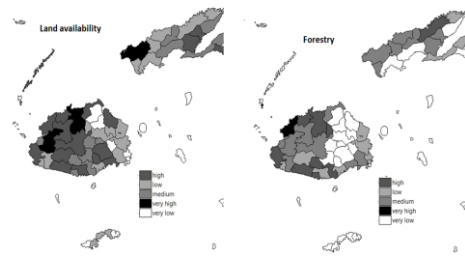


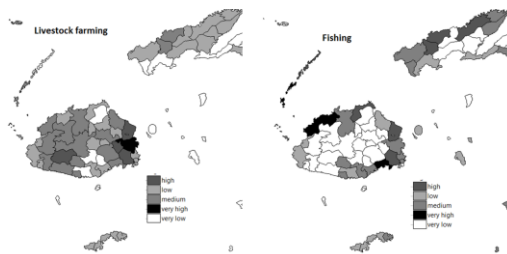
Figure 2. Flowchart of method

3.0 RESULTS AND DISCUSSION

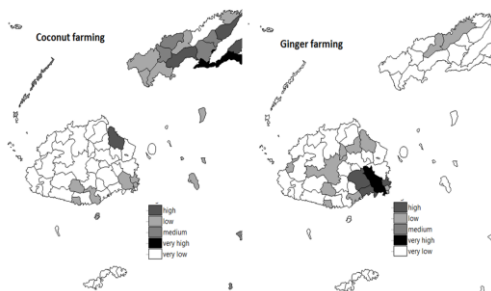
Samples of socioeconomic drivers to shifting cultivation are displayed on figures 3 to 5. They were georeferenced and converted to the raster format for map calculation with the described script. Farms between 3-50ha are mostly covered by forests (natural or planted), grasslands or fallows of over one year; shorter fallows are common in smaller farms. Land use is intense on farms under 3ha, and very intense when they are of less than a hectare. Land use intensification diminishes on parcels from 3 to 50ha, and again intensifies when the farms are of over 50ha. In farms of less than 3ha size land use is intense when (drivers in order of importance from high to low) Indo-Fijian population, household size, and land availability values are high. In farms of 3-10ha size land use is intense when the values of (drivers in order of importance from high to low) household size, subsistence employment, coconut farming, land availability, Fijian population, and population change are high. In farms of 10-20ha size land use is intense when the values of (drivers in order of importance from high to low) household size, population change, subsistence employment and Fijian population are high. In farms of 20-50ha size land use is intense when the values of (drivers in order of importance from high to low) higher education, fishing, forestry, in-migration, population density and population distribution are also high. In farms of 20-50ha size land use is intense when the values of (drivers in order of importance from high to low) population change, Indo-Fijian population, land availability, fishing and sugar farming are also high.



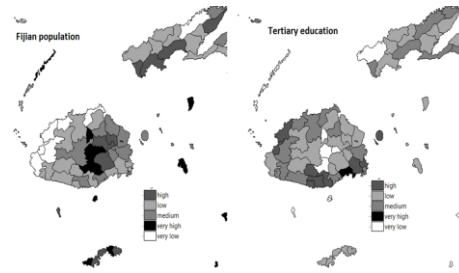
Figures 3a. Fiji islands map showing degrees of land availability per *tikina*. Range: Less than 5 to 40 km² of land —available per average village or settlement; and **Figure 3b.** The country's map showing degrees of forestry employment per *tikina* Range: 0 to 247 workers. Wood industries are Fiji's fifth most important export satisfying the domestic demands (Walsh and Crosbie 2006).



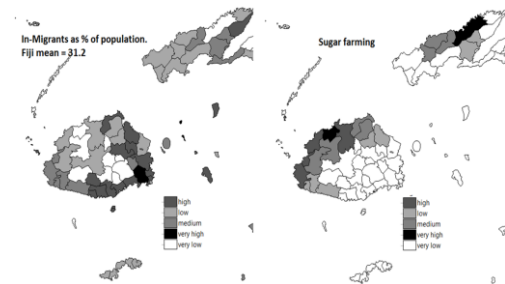
Figures 4a. Fiji islands map showing degrees of livestock farming per *tikina*. Range: 0 to 63 workers. All of Fiji's livestock production is used locally, even though the government invested heavily, little changed from 1989 to 2004 (Walsh and Crosbie 2006). **Figure 4b.** The country's map showing degrees of fishing activity per *tikina*. Range: 0 to 247 workers. Fishing at \$85million was Fiji's third largest export after garments and sugar.



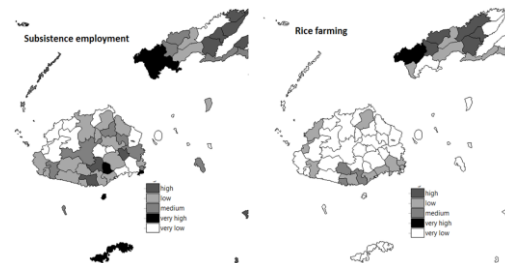
Figures 5a. Fiji islands map showing degrees of coconut farming per *tikina*. Range: 0 to 405 workers. **Figure 5b.** The country's map showing degrees of ginger farmers per *tikina*. Range: 0 to 107 workers.



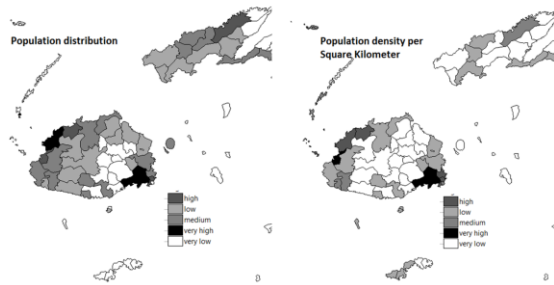
Figures 6a. Fiji islands map showing degrees (in percentage) of Fijian population per *tikina*. Range: under 45 to 100. **Figure 6b.** The country's map showing degrees of tertiary education (in percentage) per *tikina*. Range: 0 to 21.



Figures 7a. Fiji islands map showing degrees of immigration (as percentage of population) per *tikina*. Range: under 45 to 100. **Figure 7b.** The country's map showing the number of sugarcane farmers per *tikina*. Range: 0 to 7486.



Figures 8a. Fiji islands map showing degrees of subsistence employment per *tikina*. Range: 0 to 74.7% of labour force. Subsistence activities employed the half of the labour force in 1996 with a value of nearly 6% of the GDP (Walsh and Crosbie 2006). **Figure 8b.** The country's map showing the number of rice farmers per *tikina*. Range: 0 to 158 farmers. Sugar was Fiji's main export until 1988, currently employs a quarter of the active labour force (Walsh and Crosbie 2006).



Figures 9a. Fiji islands map showing population distribution (as percentage of population) per *tikina*. Range: 0 to 14.4. **Figure 9b.** The country's map showing the population density per square kilometre per *tikina*. Range: 0 to 300 and over.

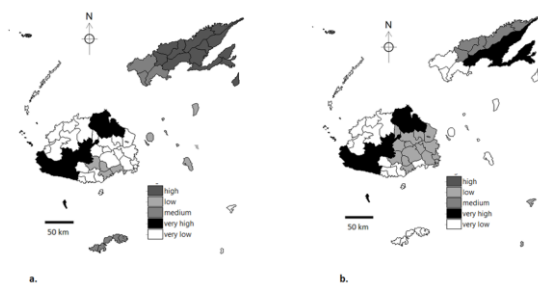
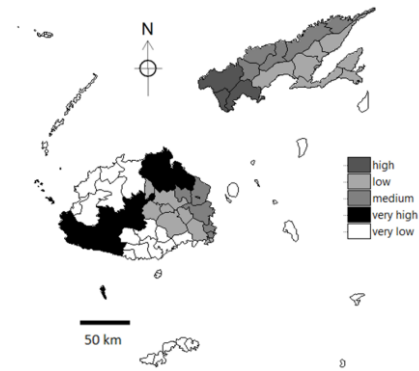


Figure 10a. LUI of farms of less than 1ha size. **Figure 10b.** LUI of farms of 1-3ha size.

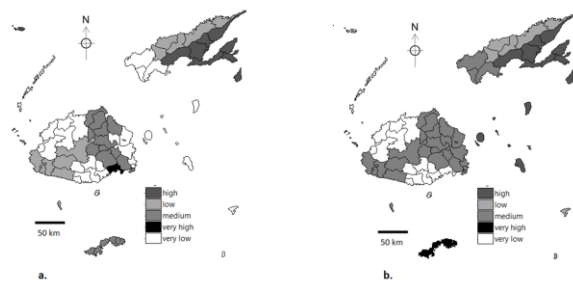


Figure 11a. LUI of farms of 3-5 size. **Figure 11b.** LUI of farms of 5-10ha size.

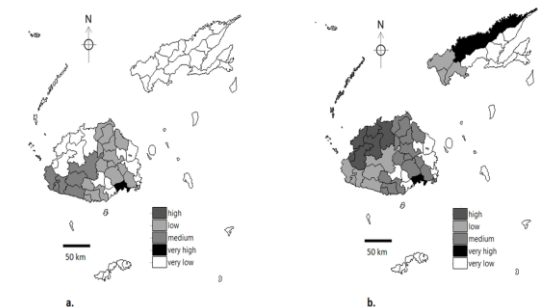


Figure 12a. LUI of farms of 20-50 size. **Figure 12b.** LUI of farms of 50-100ha size.

Figure 13. LUI on farms of more than 100ha.

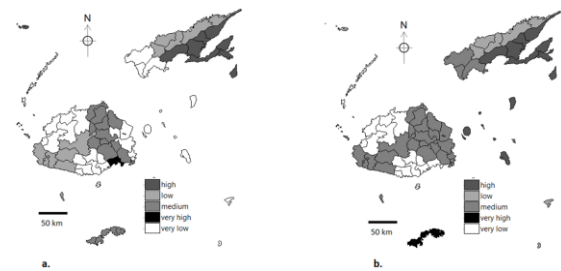


Figure 14a. LUI of farms of 3-5ha. **Figure 14b.** LUI of farms of 5-10ha farm size ranges.

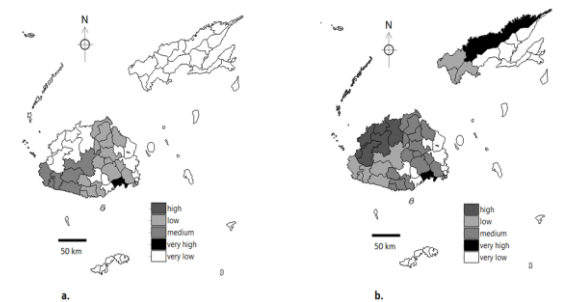


Figure 15a. LUI of farms of 20-50ha. **Figure 15b.** LUI of farms of 50-100ha farm size ranges.

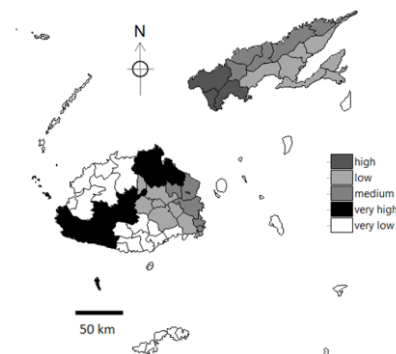


Figure 16. LUI on farms of more than 100ha.

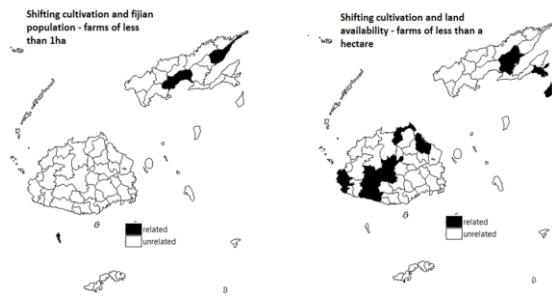
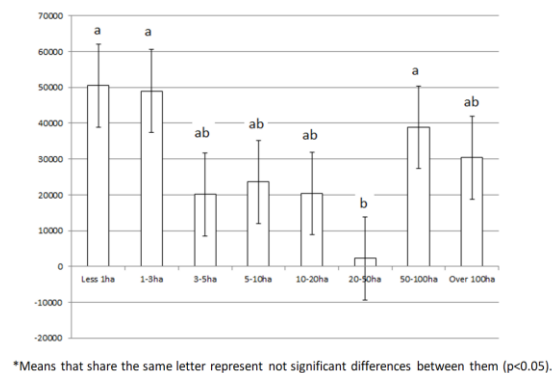


Figure 17. Critical maps for farms under 1ha showing areas with high or very high values of Fijian population and of land use intensity (a); and high or very high values of land availability and land use intensity (b).



*Means that share the same letter represent not significant differences between them ($p < 0.05$).

Figure 18. Total of pixels of areas with high or very high values of LUI per socio economic parameter. *Means that share the same letter represent not significant differences between them ($p < 0.05$).

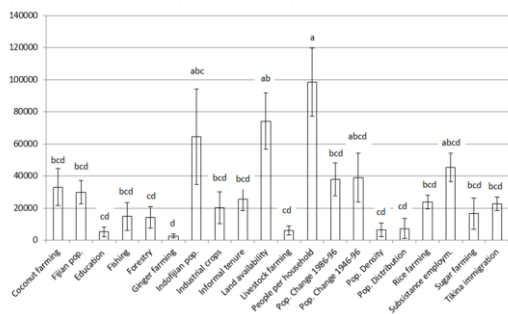


Figure 19. Total of pixels of areas with high or very high values of LUI per socio economic parameter. *Means that share the same letter represent not significant differences between them ($p < 0.05$).

4. CONCLUSIONS

Results showed significant differences among treatments ($p < 0.05$), with factors related to human demography being the most influential. In farms of less than 3ha size the land use is intense when first, indo-Fijian population, household size and lastly land availability values are high; while in farms of 20-50ha size the land use is

intense when the values of first population change, indo-Fijian population, land availability, fishing and lastly sugar farming are also high. LUI patterns normally decrease with the increase of farm size, but increase on farms over 20ha size. It is recommended to reformulate policies that will des-accelerate the rates of land use, such as the facilitation of land ownership over large farms, the gradual replacement to agroforestry systems, and the creation of more employment opportunities in the industry, tourism and services sectors of the country.

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