Dynamics of Changes in Land Use in the National Coffee Development Area in Bantaeng Regency

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Abstract. Establishing a national area for coffee development is a step forward by the government to improve the economy of farming communities. However, five years after its enactment, it shows that things differ from the desired program objectives. There are widespread changes in land use by farmers as a result of the decreasing productivity of coffee plants. This study aims to identify changes in land use and predict changes in the future. We used the Cellular Automata (CA)–Markov model and secondary data to verify the results of this study. This study found that the change from coffee land cultivation to clove land cultivation has changed the agricultural landscape in the coffee area in the last five or seven years and is projected to continue to experience significant growth in the next three years. The trend of changing coffee land cultivation to clove cultivation is a form of farmer resilience towards a livelihood that is considered more profitable. The socio-economic factors of the farming community are a serious problem. The demands of household living needs are in a position that must be hastened without careful consideration of risks in the future. Cultivation knowledge, climate change, biophysical land conditions and socio-economic conditions are essential variables that encourage farmers' behaviour in changing the landscape of their plantations.

1 Introduction

Changes in agricultural land use in rural areas are a severe problem amidst agricultural development in Indonesia. Based on the 2018 Inter-Census Agricultural Survey (SUTAS), agricultural land controlled by agricultural business households is less than 0.5 hectares, as many as 15.89 million households or 59.07% of the total farming households. Farmer households with land ownership of less than 0.5 hectares increased from 14.62 million in 2013 to 15.89 million in 2018. This condition of land ownership is caused by: [1] increasing conversion of agricultural land for agricultural purposes. Housing and public facilities; [2] land fragmentation occurring due to the inheritance process; and [3] the sale of rice fields.

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Bantaeng Regency has been designated as a national area for developing coffee plants since 2018. Four years have passed, even though the development of coffee commodities in the Regency is included as a national priority.

Bantaeng has experienced a decline in the last five years. Based on BPS data, there has been a decline in production in the last five years. In 2017, coffee production in Bantaeng Regency reached 1851.35 tons, but by 2022, it had decreased to 1404.04 tons. There was a decrease in production of 447.31 tons. This figure is quite a significant decrease, reaching 24.16%. A decline also followed this decline in production in coffee land, where there was a significant decline over the last five years, namely 1128.50 Ha or a decrease in land area of 30.87% from the land area in 2017 of 3655 Ha [1]. The decline in coffee production is caused by several factors, one of which is the physiological condition of old plants without any plant rejuvenation activities, which is exacerbated by unpredictable climate changes and farmers' poor adaptability.

Climate change is characterised, among other things, by the high frequency of extreme climate events and increasing temperatures beyond optimum conditions for plant growth [2]. This condition causes a decrease in plant productivity in areas with higher temperatures due to heat stress, soil erosion due to high rainfall, and land degradation due to increasing intensity and duration of drought [3]. Climate change impacts various aspects of life, including the agricultural sector, which is the source of the economy for most rural communities. The results of crop simulations based on climate projection scenarios conclude that the impact of climate change will be more severe in tropical areas where food crises generally occur [4]. Changes in agricultural land use also triggered the decline in coffee land area due to socio-economic activities closely related to urgent human needs. Due to climate change, the condition of old coffee plants, and agricultural systems that are not environmentally friendly, coffee productivity continues to decline. The decreasing amount of coffee land and the decline in coffee production affect farmers' incomes significantly, so many coffee farmers are changing their land to other crops with better prospects. Even in more severe conditions, many farmers change professions from farming to other professions outside agriculture.

In this study, we identify farmers' land use changes in coffee development areas and predict future land use changes using Markov-Cellular automata in coffee development areas in Bantaeng Regency. Projecting changes in land use is very important for sustainable land management. Spatial transition-based models using Markov-Cellular automata are effective models and play a central role in predicting spatial land use changes and analysing land cover changes in the future [5]. The results of this research can later be used as reference material in preparing planning policies for developing sustainable and better coffee areas. This research examines the dynamics of land-use changes in the national coffee development area in Bantaeng Regency.

2 Methodology of the paper

2.1 Study Area

The coffee development area is the study area chosen in the case study in Bantaeng Regency, South Sulawesi Province, Indonesia (Figure 1). National coffee farming area in Bantaeng Regency. This area was designated nationally based on Minister of Agriculture Decree Number 472 of 2018. Since it was designated as a national coffee development area, coffee production and productivity have declined due to widespread land use changes by farmers.

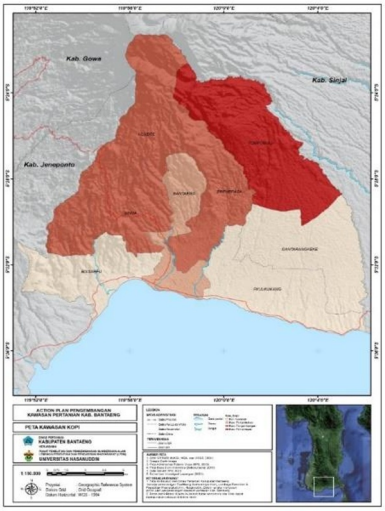

Fig. 1. Location of the study area at coffee development area in Bantaeng Regency.

2.2 Data collection

Data collection was carried out from March to August 2023. This research uses primary data in the form of data generated from field studies, such as ground check sample data, to verify existing areas. Meanwhile, the secondary data used is sourced from the needs of several maps, such as the Landsat 8 acquisition image map, which was recorded in 2016 and 2022, the 2022 RBI map from the Geospatial Information Agency, the regional administration map and the RTRW map of Bantaeng Regency as well as the DEM (Digital Elevation Model) map for provides topographical form information. We use the UTM coordinate system in the 50 South zone and WGS 1984 as the spatial map registration for the analysis.

2.3 Data Analysis

Data analysis uses Markov-Cellular automata to project land cover using data patterns from 8 Landsat images from 2016 and 2022. Satellite data was selected based on the availability of image maps with a maximum cloud cover level of 4%. Furthermore, the results of this image interpretation will be used to project changes in coffee plantation land in 2026. We did not use coffee field samples as test parameters because of the difficulty of classifying coffee plants. The classification system was determined using the interpretation of clove plants to see how clove cultivation is projected to replace coffee plants on farmers' land. The ground check location is determined using snowball sampling to identify points on the land cover map. This technique is used based on verification needs that have met the desired criteria limits. Qualitative data from farmer surveys in coffee areas is also possible as a comparison to verify the results obtained.

3 Results and discussion

The pattern of changes in coffee land cultivation shows very significant changes in the last five-year period, namely since 2017, when coffee land decreased by 975.5 ha, followed by a decrease in the production of 580.94 tonnes. The conversion of coffee plantation land cultivation functions is increasing due to the replacement of land cultivation by clove plants,

which farmers consider more capable of providing economic value than coffee plants. From 2017 to 2022, the planting area for clove plantations increased to 818 ha, followed by a clove production of 163.38 tons (figure 02). In the last five years, farmers in the coffee area of Bantaeng Regency have been massively changing coffee land cultivation into clove cultivation. Clove plants are considered capable of providing more economic value when compared to coffee plants. The condition of coffee plants is getting older, so farmers can no longer expect them to provide high productivity, and the market price of coffee at the diluent level is meagre, which adds to farmers' disappointment. On the other hand, the high market price of cloves at that time was very tempting for coffee farmers to change their land from coffee plantations to clove plantations.

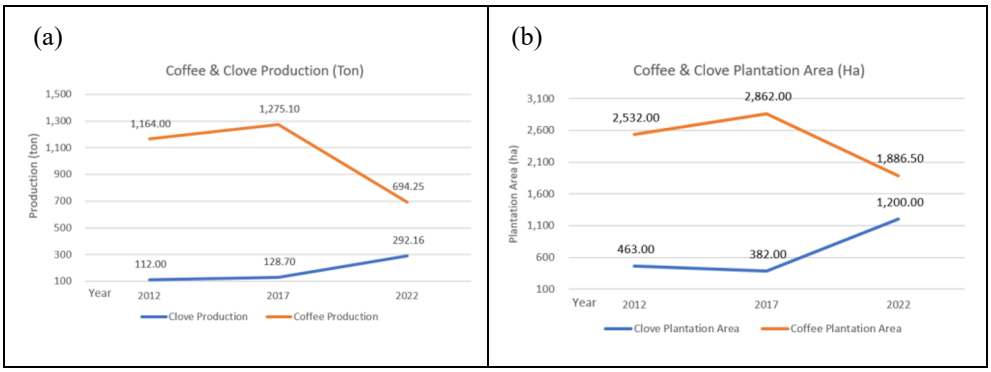

Fig. 2. (a). Production of coffee and Clove in 2012, 2017 and 2022; (b) Plantation area of coffee and clove in 2012, 2017 and 2022 (BPS, 2022).

The expansion of socio-economic needs is also directly proportional to the population growth rate in this region over the last ten years. Regional statistical data shows this growth has increased by 6,828 people (figure 03), spread across two regional sub-districts. The population growth rate also plays a vital role in driving changes in coffee land, from urgent economic needs to land needs for settlements. This is specifically for coffee land around settlements. The increasing population requires more land to meet population growth for housing needs and food production [5]. [6] also identified population growth as one of the driving forces for land function change.

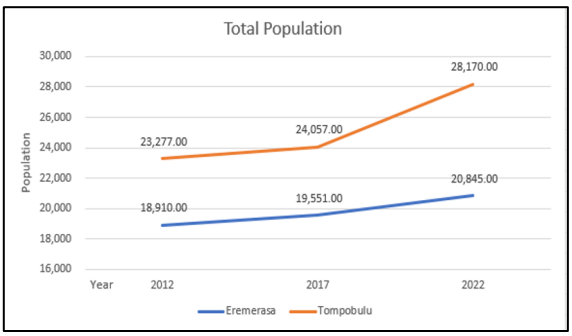

Fig. 3. Population growth in two sub-districts (Eremerasa & Tompobulu) in the coffee development area

Studying patterns of land use change in agricultural areas based on space and time is essential for understanding the socio-economic behaviour of farmers in cultivating their land

in the future. Understanding landscape change is a sustainable natural resource management strategy based on scientific evidence [5]. The simulation results provided by the CA-Markov model on changes in land use from Landsat image year maps eight records from 2016 to 2022, showing very significant land changes. This study's assessment of land use changes only focuses on the classification of changes in clove plantation land use in the national coffee development area. Changes in clove plantations show relatively high estimated values. Namely, in 2016, it is predicted to be 343.80 ha, expanding to 1,538.18 ha in 2022. The results of this simulation project's land use changes in 2026 show that the growth of clove land continues to increase to 1,665.5 ha validation results based on a kappa value of 97.5%, where this result shows a high level of accuracy.

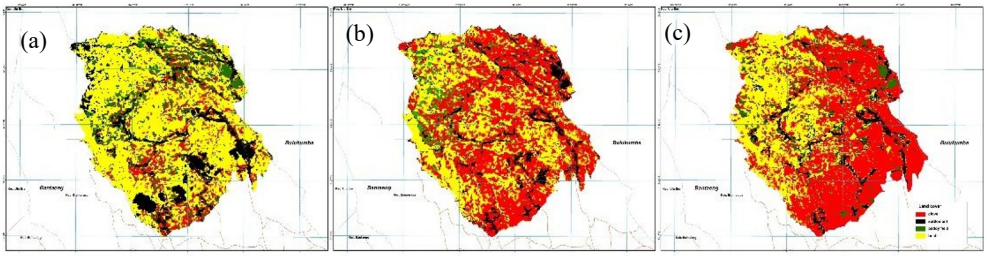

Fig. 4. Map of changes in land use in the coffee development area of Bantaeng Regency (a) in 2016, (b) in 2022 and (c) projections in 2026.

The results of this modelling also show that coffee plantation land has the opportunity to continue to be degraded by clove commodities in the future. The condition of coffee plants is old, and there needs to be more effort for coffee farmers to rejuvenate with new plants. Other commodity options have a production period. Short will be a strong driver to ensure change in the future. Government support is needed to develop coffee areas in this region so that they continue to exist and provide the most significant benefits for the welfare of the coffee farming people. Regulations related to area cultivation patterns need to be realised in policy regulations and supported by assistance with farmers' knowledge in cultivating their land.

Table 1. Farmer land conversion in the coffee development area of Bantaeng Regency.

Conversion of land use	(n)	Percentage	Average conversion area (ha)
Coffee - cloves	251	78.68%	0.36
Coffee - porang	15	4.70%	0.21
Coffee - onions	3	0.94%	0.35
Coffee - banana	6	1.88%	0.24
Coffee - potatoes	3	0.94%	0.15
Not conversion	41	12.85%	0

Source: Survey results of coffee farmers with 2019 samples

Based on a survey involving 219 farmer respondents, information was obtained that the highest conversion of coffee land cultivation was for the clove commodity, namely 78.68%, with an average conversion land area of 0.36 ha (table 01). Farmers do not ultimately convert coffee land. Coffee may remain their primary source of income. Farmers began cultivating clove plants to replace old and no longer productive coffee plants.

The results of this research provide information that the projected decrease in coffee land in this area is an actual picture of the increasing erosion of this commodity in the future, and this is a real threat to the loss of local commodities, which have been the economic backbone of village communities in this area. The factors driving the transfer of commodity business functions in this region need to be taken seriously by policymakers in maintaining the sustainability of superior coffee commodity businesses so that they continue to exist and provide tangible benefits to farmers. Even though, in the regional context, this change in land use provides a natural increase in value economically, there needs to be a fundamental change to the economic conditions of farming families. Changing plantation crops from coffee to cloves requires a reasonably long time to grow to a productive age, namely 4.5 to 6.5 years. Farmers did not consider this transition period. During this period, farmers experienced difficult economic conditions. This is then exacerbated by extreme climatic conditions due to climate change, which impacts young clove plants. The suitability of growing coffee plants along with climate change, which results in changes in temperature and unpredictable seasons, is starting to be felt by coffee farmers in this area. This has a significant impact on the development of coffee areas as a whole. Coffee plantations in low-lying areas tend to feel the real impact; they began to complain that production was decreasing, but farmers in areas with altitudes above 1400 meters above sea level tended to remain stable.

3.1 Projected changes in land use

Projections of changes in land use in the coffee area in the future show changes that continue to increase, where the decline in coffee land area continues to increase by 5.3% in the next four years. The simulation results predict that the decline in coffee land in the future will still be influenced by farmers' transfer of land cultivation for clove plants. This will be a strong warning to the government regarding the relatively high rate of decline in land exploitation for coffee crops. The government's policy of designating Bantaeng Regency as one of the national coffee development areas has little effect on regional scale-based coffee development. In many developing countries, environmental problems related to coffee production usually cannot be resolved by implementing regulations and policies due to weak government institutions [7]. The determination of national areas as government regulation in the long-term development of coffee farming needs to be closely monitored by local government institutions through a policy approach that is more pro-farmer. On the other hand, farmer participation in agricultural programs is an essential factor in rural development because it plays a significant role in poverty alleviation [8].

3.2 Changes in land use as a form of farmer resilience.

Coffee farming will be resilient if it can provide economic and ecological benefits and is socially acceptable to the surrounding community. The agricultural development paradigm, which focuses on increasing production and productivity as parameters for measuring farmer welfare, must be changed. High production does not always reflect farmer welfare. So, the best agricultural development paradigm should focus on welfare, which can be measured by a decent standard of living for farming families. Currently, farmers need more hope of cultivating coffee plants as a staple crop for the family's primary source of income. The decline in production and productivity of coffee plants due to old coffee plants where coffee is > 23 years old is 68%. This is due to farmers' need for knowledge about good coffee cultivation and the rejuvenation of old plants, so there are no steps to anticipate this. Another condition that could be improved is farmers' increasingly narrow land ownership due to distributing coffee land as a family inheritance to their children. The smaller area of land ownership does not provide economic viability for business, so those with limited land must

survive through diversifying livelihood strategies outside of agriculture. Appropriate farm and farm-level adaptation practices must be adapted to local socio-economic conditions [9]. This can vary among coffee farmers, even within a single landscape. This variation is related to access to resources, education, land and land area, and other household activities [10].

Uncertain climate conditions also exacerbate this condition. This variable backfires for farmers. Climate is a variable that cannot be controlled and is difficult to predict. Farmers' perceptions of uncertainty regarding the impacts of climate change and the strategies implemented have a direct effect on the livelihoods of rural farmers, so recognising supporting and limiting factors for climate adaptive behaviour, as well as alternative policies held by decision-makers greatly determines farmers' attitudes in the future [11]. Adaptation to climate change is a critical aspect that must be on the national development agenda. Indonesia's climate change adaptation agenda aims to integrate climate change adaptation into national development planning. [12] states that adaptive capacity is closely related to social and economic development. Mitigation is an effort to overcome the causes. Mitigation is carried out to reduce future risks and impacts of global warming and climate change [13]. Determining how to overcome these adaptation efforts is a challenge because we need to overcome the impacts of climate change while simultaneously overcoming barriers to its implementation in local communities and trying to take advantage of existing opportunities [14].

In this study, we further highlight farmers' low level of knowledge in various aspects of agricultural commodity business, starting from understanding the economic value of a commodity, cultivating land and the ability to process and market agricultural products. The deficient education of farmers in this region has provided an accurate picture. Although education at school is not the only variable that influences the low capacity of farmers in cultivating agricultural land, education at school will be their essential capital to build a solid foundation in childhood. To develop their capacity and open their horizons in the future. Likewise, the results of research by [15] suggest in a case study that education is a critical factor in increasing the perception of farmers' adaptive capacity, especially children's access to primary education. Resilience in coffee farming should not only focus on sustaining production, maintaining productivity or generally focusing on cultivation activities, but the most important thing is how the welfare of coffee farmers is the core of developing coffee areas in this development area, building productivity as the primary goal of regional development is not always guarantee the welfare of coffee farmers, various variables greatly influence farmers' income, land area, physiological condition of coffee plants, availability and price of inputs, selling price of coffee and quality of coffee, sometimes making coffee farmers suffer during an abundant harvest. In some conditions, a diversification livelihood strategy is the final step that we recommend if farmers cannot provide economic value in land ownership based on their area.

4 Conclusion

Most of the changes in land use by farmers are carried out due to urgent economic needs. Poor farming families, whose source of family income only depends on land use, will be in a complicated situation when coffee production continues to decline and selling prices are less profitable. On the other hand, they need more time and good information to make the right choice and take action to convert coffee land into other crops. Increasingly narrow land ownership, the condition of old plants without any plant rejuvenation activities, and the impact of climate change on coffee plants have become real threats to reducing coffee production. The unpreparedness of coffee farmers exacerbates this condition of facing the impacts of climate change and limited access to climate development information by farmers in the coffee area. The results of this study have provided important insights and information

for stakeholders that will contribute to better management of coffee areas. The direction of these findings highlights policymakers in implementing sustainable land use planning through mitigation and strategic policies.

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