FALLOW++: as impacts assessment tool of some land-use options with regards to negotiation process on a changing landscape

Meine van Noordwijk, Betha Lusiana and Desi Suyamto
ICRAF SEA Modelling Group
October 8, 2002

RINGKASAN

FALLOW++ merupakan suatu model dinamika landsekap yang mencoba menangkap proses-proses dinamis tahunan dari: (1) kesuburan tanah pada tingkat plot dan bagaimana kesuburan tanah tersebut akan diterjemahkan dalam produktivitas tanaman pertanian; (2) daya dukung seluruh landsekap dalam memenuhi kebutuhan masyarakat dalam hal kecukupan pangan ataupun ekonomi rumah tangga; (3) bagaimana masyarakat berstrategi untuk memenuhi kebutuhan pangan ataupun ekonomi rumah tangga mereka; (4) bagaimana masyarakat mengimplemantasikan strategi mereka dengan mempertimbangkan ketersediaan ataupun aksesibilitas sumberdaya; dan (5) bagaimana implementasi masyarakat akan berakibat mengubah landsekap dan berimplikasi mengganggu proses-proses biofisik, baik pada proses suksesi ekologi maupun pada proses pemulihan kesuburan tanah, yang pada akhirnya akan mempengaruhi daya dukung landsekap, fungsi-fungsi tata air, keanekaragaman hayati, maupun cadangan karbon. FALLOW++ dikembangkan dengan menggunakan alat pemodelan yang mempertimbangkan aspek keruangan secara eksplisit, yaitu PCRaster, sehingga sangat memungkinkan untuk mengaplikasikannya menggunakan data-data spatial pada lokasi yang nyata. Model ini dirancang untuk bisa dipergunakan sebagai alat bantu penilaian dampak dari beberapa opsi penggunaan lahan dalam kaitan dengan proses negosiasi pada suatu wilayah.

ABSTRACT

FALLOW++ is a landscape-dynamics model, which comprises of the following main annual dynamic processes : (1) plot-level soil fertility based on Trenbath and how it affects agricultural crop production; (2) carrying capacity of the whole landscape to satisfy people in term of food sufficiency and/or household economics; (3) how people plan their strategy to satisfy their food need requirement and/or their household economics as they have learnt from past experiences; (4) how people implement their strategy relating to availability and/or accessibility of resources; and (5) how people's implementation will consequently change the landscape by interfering biophysical processes on either ecological succession or soil fertility recovery, thus affecting carrying capacity of the landscape, watershed functions, biodiversity, and carbon stocks. FALLOW++ was developed using a spatially explicit modelling environment of PCRaster, making it possible to apply the model using real spatial set of data. Therefore, FALLOW++ is a useful impacts assessment tool for land-use options and can assist the negotiation process between stakeholders in a changing landscape.

Keywords: landscape-dynamics model, annual time step, soil fertility-crop productivity, carrying capacity-household economics, strategy, implementation, consequences, spatially explicit, raster, assessment tool, negotiation process.

1. Introduction

FALLOW++ has been developed as part of efforts in integrating some knowledge from various views of understanding on landscape-mosaic-resource interaction by considering roles of actors/stake-holders in transforming the landscape, biophysical responses from plot- to landscapelevels through scaling rules, and actors'/stake-holders' feedbacks on changing landscape. FALLOW++ has been designed as impacts assessment tool at landscape level to support negotiation process to have better live and landscape. Thus, the overall conceptual framework of FALLOW++ is still in line with the spirit of World Agroforestry Centre in transforming lives and landscapes.

Logical sequence of core modules of FALLOW++ (Figure 1) is started from the dynamic process of soil fertility at plot-level based on simple Trenbath model, where soil fertility is depleted during cropping period and recovered during fallow period, which current fertility could then be interpreted in term of agricultural crop production. Total crop production from the whole landscape together with other yields gained from some other economical production systems (*e.g.* agroforestry, forest resource utilisation activities, monoculture plantations) will then determine carrying capacity of the landscape in term of food sufficiency and/or household economics. People, through learning process from their experience, will then make strategic-decision regarding agricultural land demand and/or labour allocation for various economical production activities. In term of agricultural land demand — people will select suitable plots for cultivating crop, which may be done based on their knowledge on attractiveness of the plots, which is determined further by relative soil fertility and/or land accessibility with regards to transportation costs or land tenure, by considering land-clearing labour availability. People's preference on the type of cultivated crop may be based on their knowledge about crop response to soil fertility from some available choices. Activities related to agricultural land expansion will disturb natural succession as well as soil fertility recovery processes of the cleared plots.

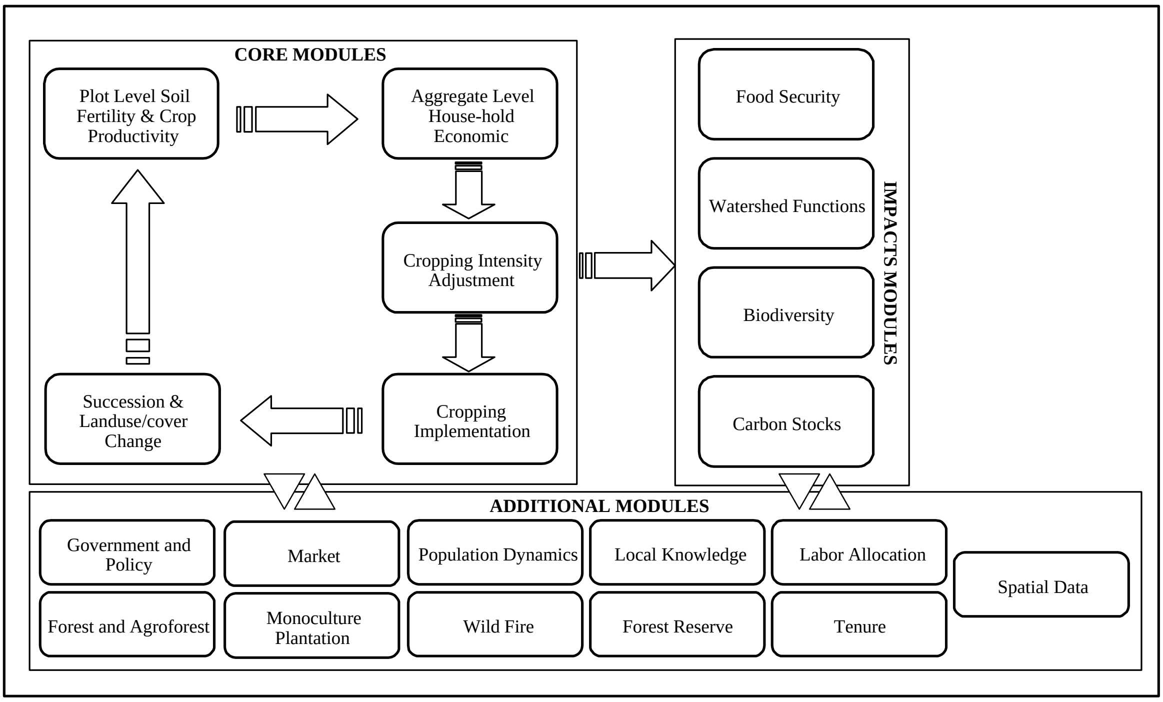


Figure 1. Conceptual framework of FALLOW++.

FALLOW[1] initialised the model development with the main concern on shifting cultivation system, and now FALLOW++ has been improved by incorporating further sequence of land-use and/or natural resource utilisation systems, ranging from agroforestry, ntfp gathering, timber

[1] FALLOW stands for (F)orests, (A)groforests, (L)ow-value-(L)andscape, (O)r, (W)astelands?

harvesting, monoculture plantations and horticulture systems. Some other modules regarding government and policy, market economy, population dynamics, forest reserve arrangement, wild fire, and tenure recognition are also taken into account.

Moreover, FALLOW++ provided some calculation procedures to assess the consequences of landscape dynamics in term of carrying capacity, watershed functions, biodiversity, and carbon stocks.

In this paper, we will overview the model, and then present example on model application in reconstructing land-use/cover change history with its consequences in Sumberjaya, in order to show how FALLOW++ could be used as a tool in supporting negotiation process.

2. Model overview

2.1. Core Modules

Plot-level soil fertility and crop productivity

In order to capture farmer's understanding on soil fertility, any chemical/physical properties affecting soil fertility at plot-level are simplified into qualitative scale. Following Trenbath, soil fertility is assumed to decline during cropping period at certain rate and improve during fallow period at certain half time of recovery. Fertilizer application may affect soil fertility through reduction on depletion rate and half time of recovery. Current soil fertility of cultivated plots can be translated further in term of crop productivity by considering conversion efficiency of the crop. Crop sensitivity to any weather variability is also taken into account.

Aggregate-level household economics

Compared to its ancestors (CDFU and FALLOW), FALLOW++ has explicitly incorporated open economy by fully integrating household and market, where people can exchange food, and by introducing financial capital as alternative reserve instead of food store. Hence, potential crop yield as such is not the only basis to adjust cropping intensity at all, since food store itself can now be affected by people's ability to buy food from market using their monetary reserve that may come from any other economical production activities or even from government subsidy or any other loans. People's decision on buying or selling food is based on current condition of food reserve and monetary reserve, aversion risk to sell food, and transaction cost in food selling.

Therefore, besides harvested crop yield, store loss fraction, and people's consumption, food store is also determined by food exchange, while financial capital is determined by incomes earned from food selling and any other economical production activities, as well as by non-food consumption. In term of food consumption, weighting factors parameters in food consumption from various types of food crop are put into consideration.

Strategic-decision making

Strategic-decision made by people reflects the way on how they have learnt about some economical production systems from their experiences. It will affect not only strategic-decision regarding cropping intensity adjustment, but it will also affect the decision on labour allocation for various economical production activities. In some cases, strategic-decision regarding agricultural land demand (cropping intensity/cropping ratio) can be made based on non-learning process, which is more on evaluation on the current condition of food reserve, whether it is sufficient or not to feed people.

Cropping implementation

Two rules in cropping implementation in term of field selection are provided. The first rule is that people will cultivate plots consecutively based on fallow and cropping period, which are functions of cropping intensity. In the second rule, people may choose the fields freely, according to their knowledge on field attractiveness. Implementation module in FALLOW++ also considers farmer's choice to the type of crop.

Succession, land-use/cover change

Compared to other land-use change models, FALLOW++ has explicitly considered succession process of fallow-type vegetations. For non-fallow-type of production systems with relatively long production period (*e.g.* monoculture plantations), FALLOW++ considers the dynamics of production stage.

In FALLOW++, land-use evolution from traditional shifting cultivation to the adoption of more modern production systems like monoculture plantations is based on logical historical pathway, where shifting cultivation may trigger agroforestry development that may lead subsequently to land privatisation, through which people can exchange their lands that may enlarge land-holding size, from which they are able to adopt more modern systems of production.

2.2. Consequences Modules

Carrying capacity

Carrying capacity of a landscape could be assessed on how does the landscape suffice people food or how is its attractiveness to pull people with regards to some economical indicators such like returns to labour or income per capita.

Watershed functions

Assessments of watershed in FALLOW++ cover the assessments of landscape filter functions on water flow, as well as on soil erosion/sedimentation, by considering annual statistic of rainfall, soil physical quality of each plot and topography of the landscape.

Biodiversity

Scaling rule and overlapping probability are considered in order to aggregate species richness from plot-level into landscape-level.

Carbon stocks

Aboveground carbon stocks are assessed directly from the land-cover type, while belowground carbon stocks are function of soil fertility. Aboveground carbon loss due to slash-and-burn/wild fire, or any other activities with significant aboveground carbon removal are considered.

3. Example of model application: reconstructing land-use/cover change history in Sumberjaya

We initialised the simulation from totally forested landscape, which was occupied by 5 inhabitants/km^2 of people who had a relatively adaptive learning style. Human population increased according to natural growth and migration that were determined by food sufficiency and returns to labour respectively. Shifting cultivation was the first livelihood recognised in the area, which fallow duration was affected directly by food need. Market had been recognised at this early stage. People then adopted coffee agroforestry and ntfp gathering activities as alternative livelihoods. Later, agroforestry development led to tenure recognition and land privatisation, through which people had the power to exchange their lands, which might lead to increase land-holding size to start adopting more modern type of production system, which was monoculture coffee plantation. In more profit-oriented type of people, market dynamics could trigger people to alter tree-based production systems into horticultural production systems, which was more promising in term of profit that could be earned.

Land-use/cover dynamics

Figure 1 summarised simulation results of landscape dynamics in Sumberjaya for 100 years period, based on above scenario. Figure 2 shows the historical pathway of land-use dynamics in Sumberjaya.

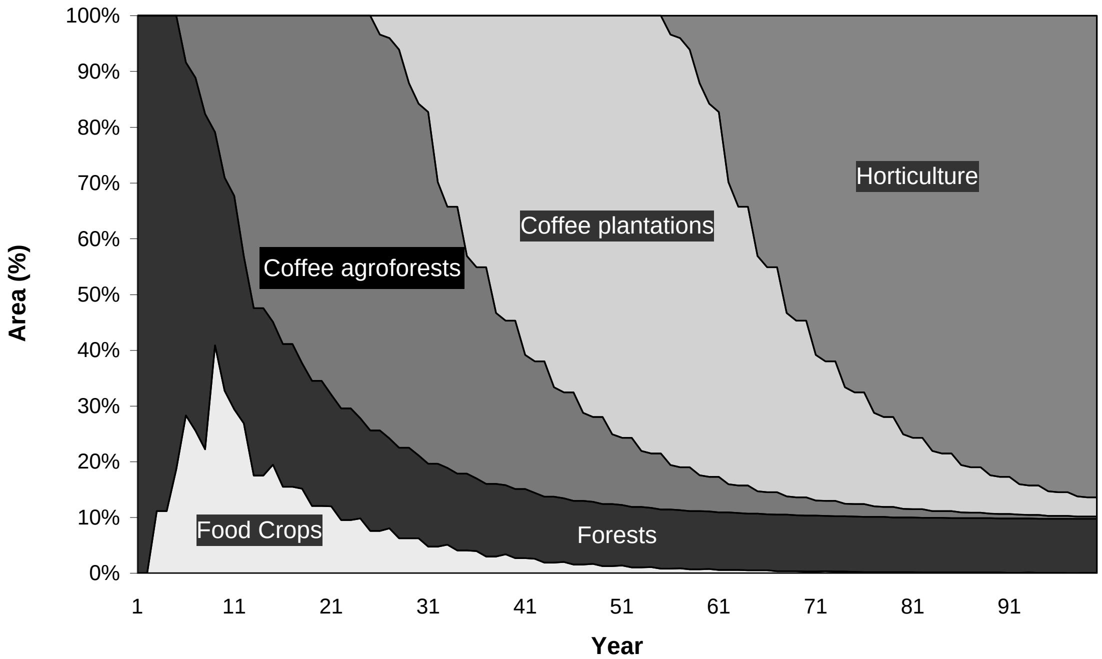


Figure 2. Simulated land-use/cover change in Sumberjaya. Remaining forested area was protected forests.

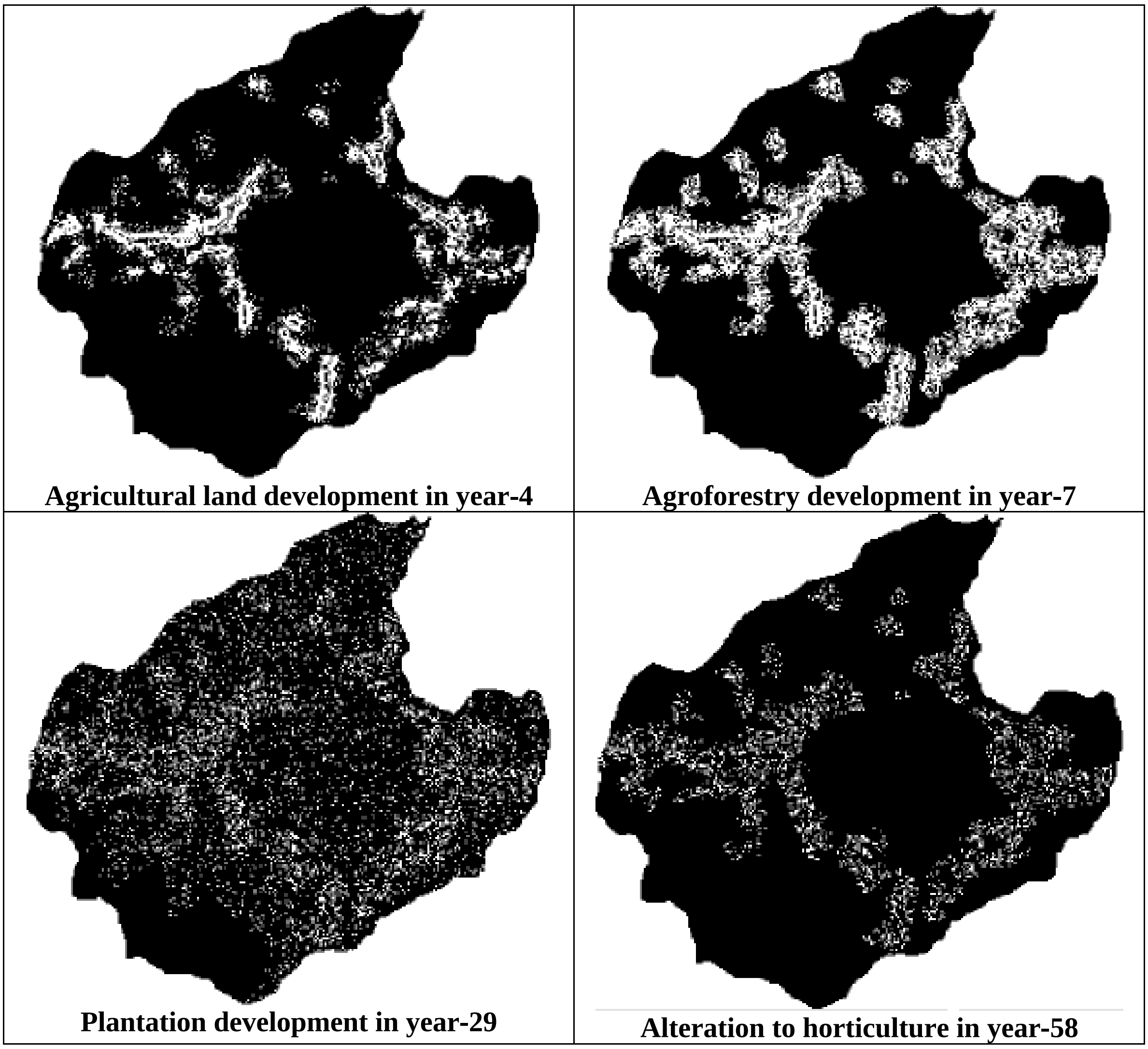


Figure 3. Historical pathway of land-use dynamics in Sumberjaya as reconstructed by FALLOW++.

Carrying capacity

In term of food sufficiency, carrying capacity of the landscape crashed at the population density of about 154 inhabitants/km^2 in year-25 (Figure 4, top). In term of returns to labour, attractiveness of the landscape crashed when people started to adopt horticultural system, since such system exploited soil fertility at relatively high degree (Figure 4, bottom).

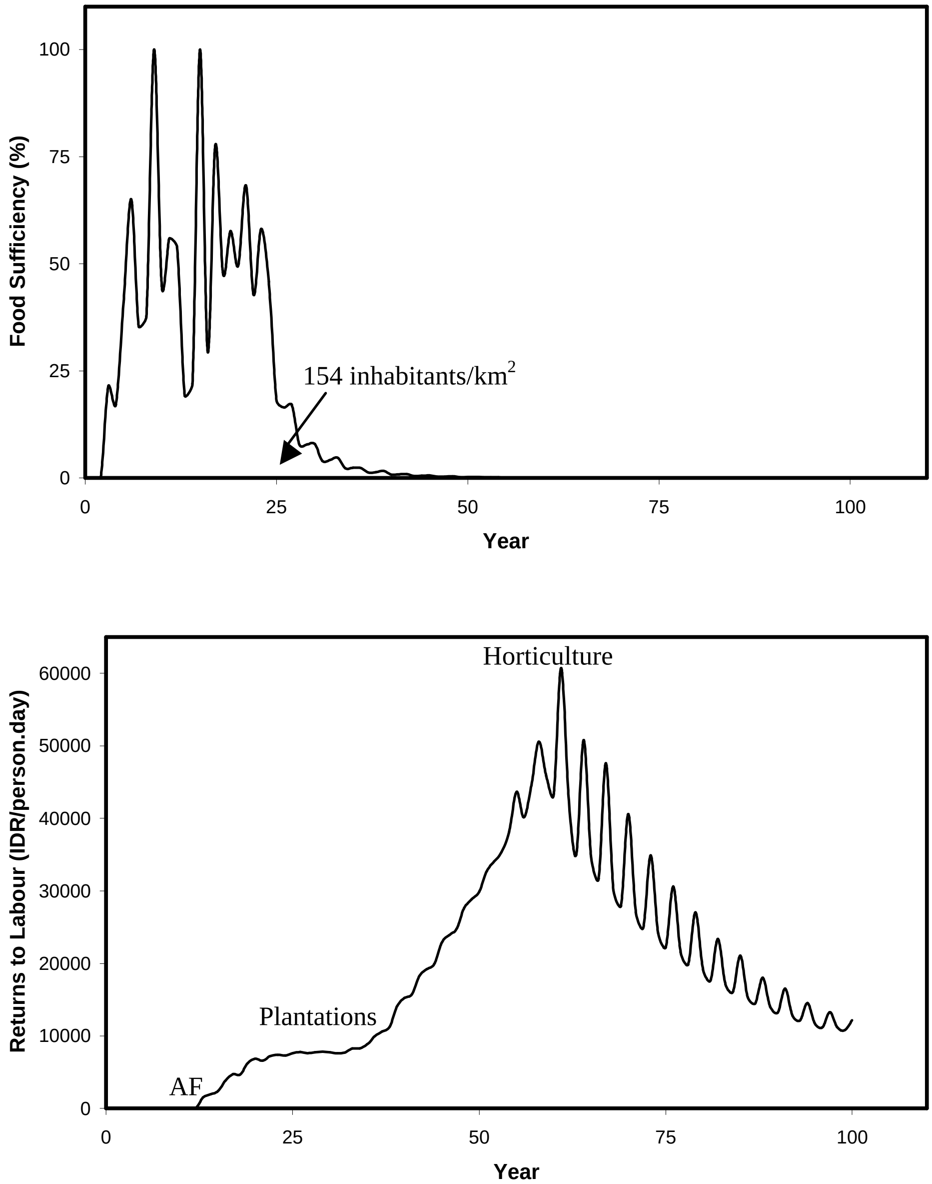


Figure 4. Landscape carrying capacity in Sumberjaya over a century period.

Household economics

At early stage, since there was no food surplus from agricultural activities, NTFP was the main income source. Until the end of the century, agroforestry still contributed to household income (Figure 5).

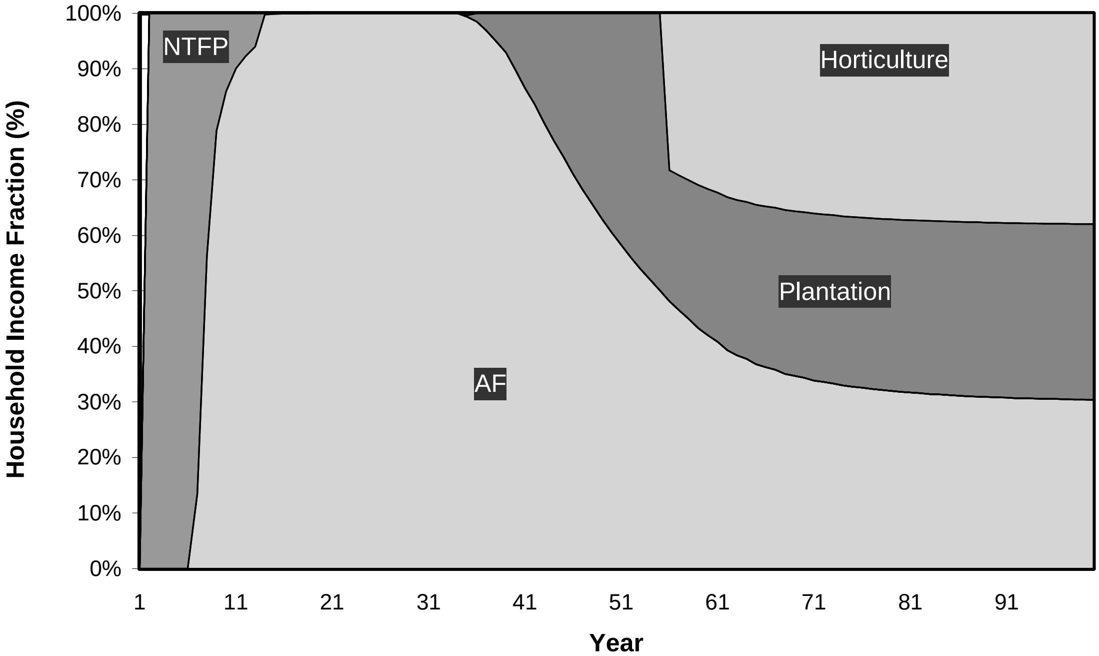


Figure 5. The dynamics of people livelihood in Sumberjaya.

Crop type dynamics

Figure 6 shows that as preference on the type of cultivated crops reflected on how people adapted to changing soil fertility, cassava dominated cropping area when soil fertility declined, since cassava has wider range adaptability to soil fertility.

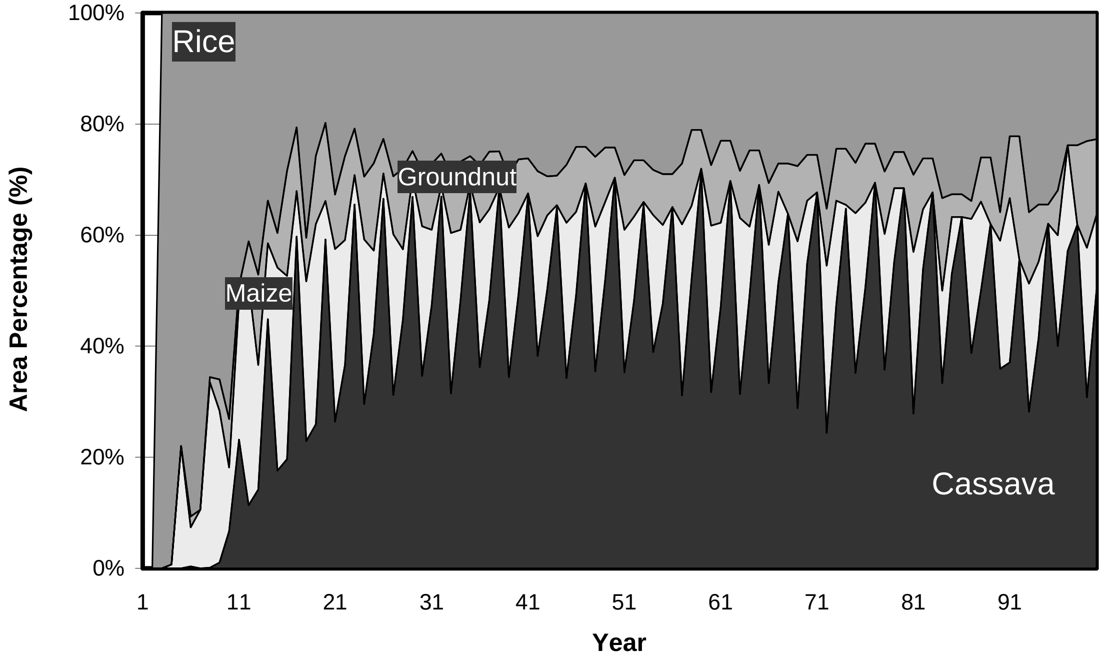
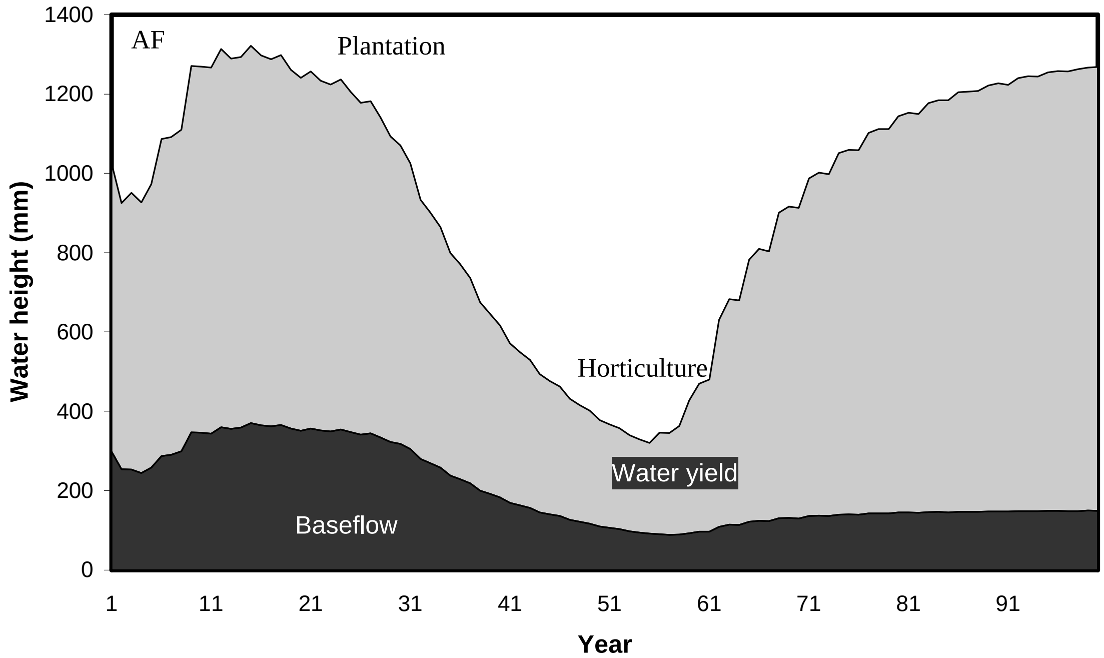


Figure 6. Dynamics on the choice of cultivated crops in Sumberjaya.

Watershed functions

Due to relatively higher water use, agroforestry and plantation types of vegetations yielded lower water yield compared to horticulture, while those two tree-based production systems could maintain soil physical properties, so that they could result relatively higher baseflow (Figure 7, top). In term of sediment loss, tree-based production systems of agroforestry and plantation could decrease sedimentation (Figure 7, bottom).



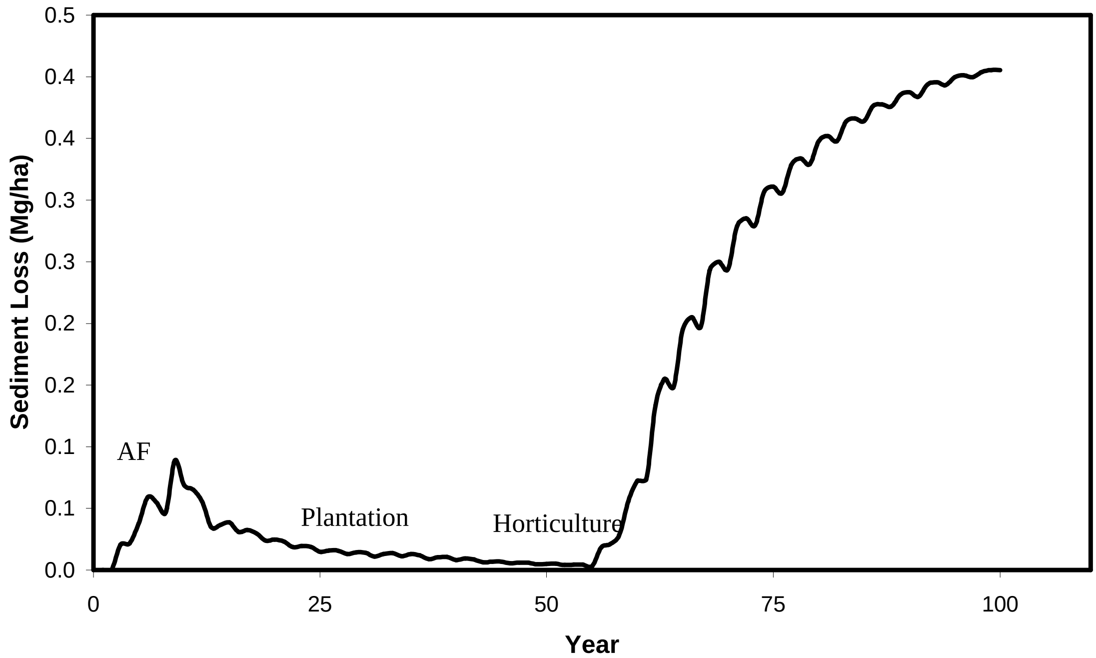


Figure 7. Consequences on watershed functions.

Biodiversity

Since the development of monoculture plantations, both plot- and landscape-level of biodiversity decreased (Figure 8).

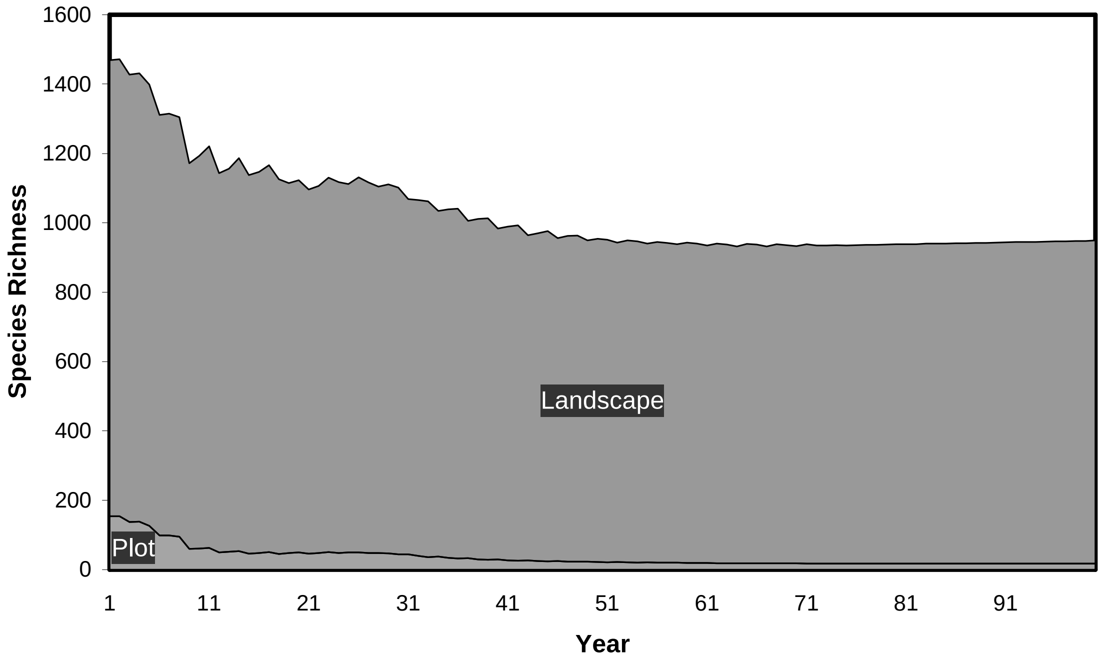


Figure 8. Consequences on biodiversity.

Carbon stocks

Triggered by plantation booming, time-average carbon stocks of the landscape declined mainly due to land-clearing and dynamic land conversion. Increase was caused by forest reserve (Figure 9).

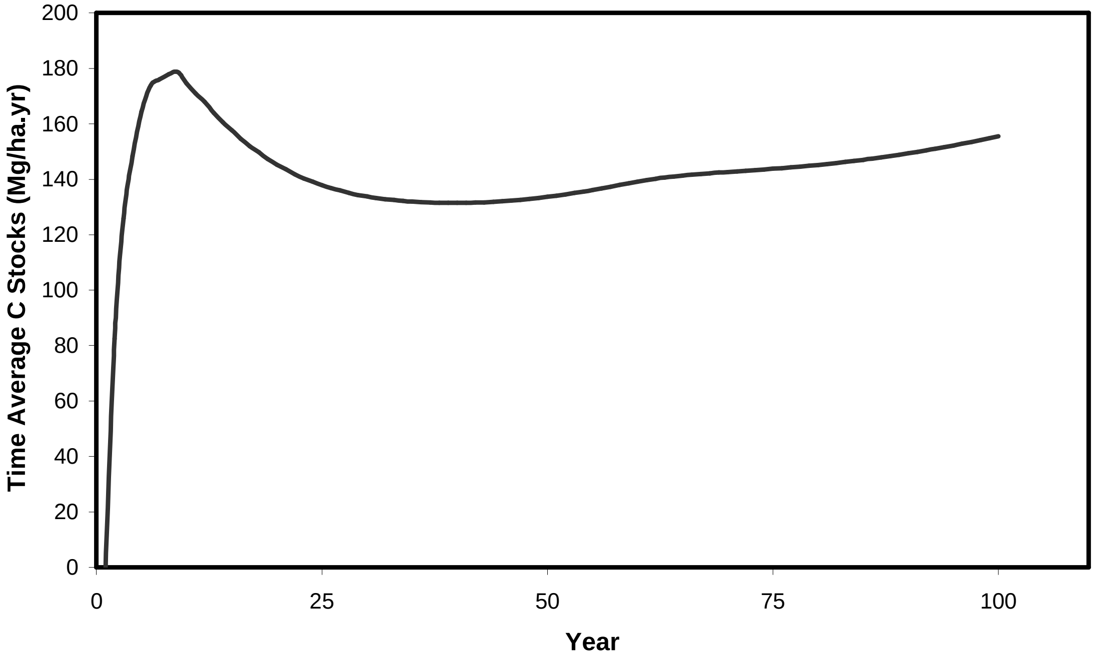


Figure 9. Consequences on carbon stocks.

4. Discussion

Results of simulation in reconstructing land-use/cover change history in Sumberjaya presented in this paper might have not captured the reality, mainly because the scenario development and model parameterisation have not been done precisely. But, from the existing results, we may learn how such landscape-mosaic-resource-actors/stakeholders interactions were simulated by FALLOW++ and how intervention could actually be made with regards to some consequences.

It is obvious that adoption of horticultural systems resulted negative impacts on all performance indicators of the landscape, either from economical or biophysical point of view. Prevention on the adoption of such non-tree based production systems could actually be done by providing incentive for farmers to maintain tree-based production systems through for instance market regulation by increasing the prices of tree-based production system products.

If global needs on biodiversity and carbon stocks are then taken into account, land conversion due to the adoption of monoculture type of tree-based production systems should be decelerated by providing incentive for farmers through ecosystem service rewarding mechanism.