Protected area

Protected forest area is about 33 000 ha or 75% of the total forest area (1995). Most of the remaining forests are found in the 18 Catchment Forest Reserves and the Amani Nature Reserve in the southern part of the East Usambaras, which is the largest continuous forest area (8300 ha) along with the Nilo Forest Reserve in the northern part of the East Usambara highlands.

Forest transition and spatial pattern of deforestation

Forest transition theory was first coined by Mather (1992) to describe the transition of forest at the country level, which starts from continuous decline of natural forests up to a certain point where 'forest' cover increases in different forms either owing to demands for forest products or to the abandonment of agricultural land of low intensification over other income generation, presumably non-land-based activities. We use a forest transition curve to capture varying stages of transition in the five landscapes based on their forest cover (Figure 35), forest dynamics, forest fragmentation, the pattern of changes and the drivers, in order to help us compare and understand the dynamics and to look for different options for interventions that are suitable for each site.

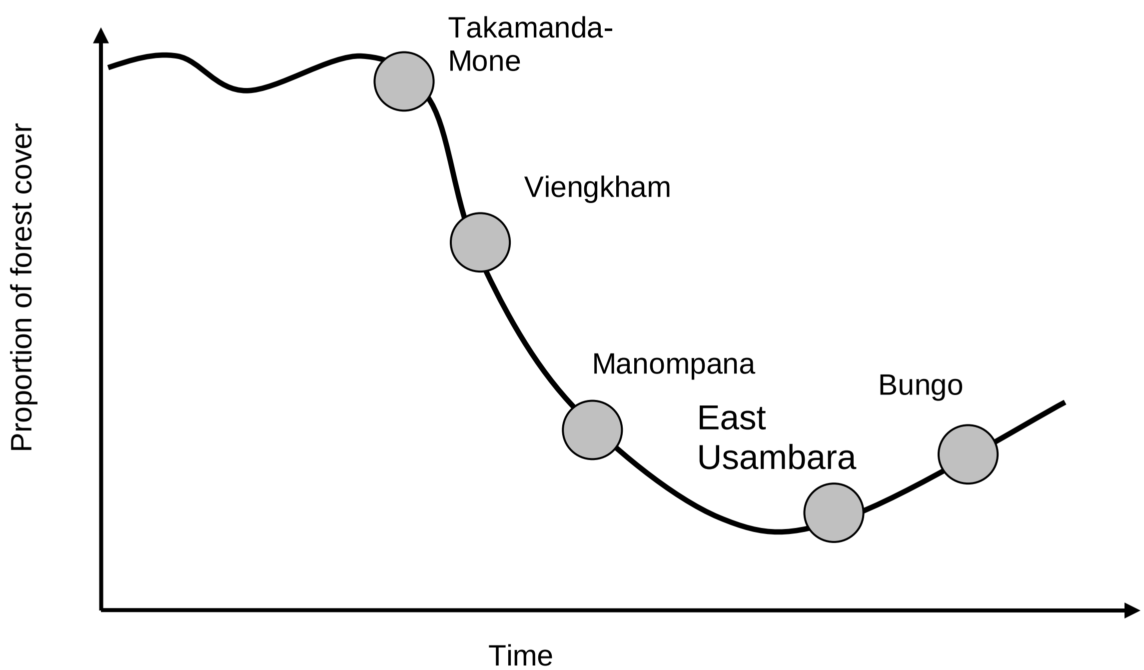

Figure 35. Forest transition stages of the five sites

Takamanda-Mone landscape is at the earliest stage in the curve, quantified by its highest proportion of forest cover and lowest rate of forest loss. Population pressure has perhaps started to increase lately but, compared to other sites, the pressure is much lower. Forest in the Viengkham landscape is perhaps protected by its rough topography even though lately there seems to be a new pattern of increasing deforestation at high altitudes inside the forest core. The

Manompana landscape has lost significant forest cover in the earlier period, resulting in a fragmented forest. More recently, the rate of deforestation has slowed. However, the expansion of deforestation in the core area should be noted.

East Usambara currently has twice as much proportion of forest cover in the landscape compared to Bungo but, in absolute forest cover, Bungo is higher. In many aspects the two landscapes are comparable, especially given the existence of large-scale operations in addition to smallholder farmers as land managers and the interaction between the two. However, owing to differences in topography and the dominate land-use systems that replace forest, the two landscapes bifurcate along the forest transition path. In East Usambara, the roughness in terrain is more distributed compared to that in the Bungo landscape. Natural forest in flat areas outside protected areas, which has higher probability to be converted, is higher in East Esambara and, therefore, if future land-use and land-cover changes follow the same trend as in the past, we could anticipate further reduction in forest cover in East Usambara compared to limited availability and accessibility of natural forest in Bungo landscape. Based on this, we position East Usambara and Bungo at a similar level of the y-axis but on different sides of the x-axis with regards to the lowest possible forest-cover level.

The spatial pattern of deforestation across the five landscapes can be summarised based on topography and accessibilities depending on the stage of forest transition.

- In landscapes with varying surface roughness, that is, relatively flat in one part and rough in others, early deforestation takes place in flat areas with high accessibility and in the later stage on the edge of remnant primary forest blocks, which partly are protected by law and topography (Bungo and East Usambara).
- In uniformly flat landscapes with low access, early deforestation predominantly happens along the river and road networks and expands from there (Takamanda-Mone) and, once forest is more fragmented, deforestation also happens in the form of encroachment on primary forest block as well as expansion of those along the transportation network (Manompana).
- When a landscape is almost uniformly rough in terrain with low accessibility, deforestation follows settlement placement in areas which are relatively flat locally and close to the river (Viengkham).

Each of the five landscapes has some protected areas delineated within it. If treated in a segregated manner, the protected areas will be left as isolated small island(s) of submontane primary forest (see the case of Bungo and East Usambara). In this case, at the landscape level, conservation of biodiversity will not be achieved for at least two reasons: (i) management and enforcement are often weak; (ii) protected areas are often delineated in remote, rough terrain that does not represent various eco-regions with various species assemblages and endemism (only α-diversity is maintained but not β- and γ-diversities); (iii) the extent of protected areas sometimes is not large enough to allow minimum viable populations so that in the long run species extinction might continue to happen; (iv) protected areas without buffer zones and corridors can easily be isolated areas rather than an integral part of a landscape. Multifunctional landscapes that accommodate conservation and development need to be considered as integrated, rather than segregated, systems. This can answer the necessary-but-not-sufficient problem of protected areas. Land-use plans that aim to increase multifunctionality of landscapes should be informed by the current status of landscape composition and configuration, the process of land-use and land-cover changes in the past and likely in the future, areas that are vulnerable to changes in the future and options for intervention. The land-use planning process should be conducted within a negotiation process among multiple stakeholders.

Global landscape composition

Two global landscape composition indices presented here are Modified Simpson's Diversity (MSDI) and Evenness indices (MSEI). Please note that the Simpson's indices were used as measures of diversity of patches and, therefore, habitat, rather than biodiversity measures (Figure 36 and 37).

Landscapes like Cameroon's Takamanda-Mone, which is highly dominated by forest in large contiguous patches, show very low diversity and evenness indices. The other four landscapes show comparable diversity indices, but different temporal pathways. With deforestation and forest conversion, the MSDI tends to increase in the Bungo landscape over time and there is a drop in the diversity index between 1999 and 2002 within which tree-based systems dominate the landscape. More recently, with some conversion of tree-based systems into more intensified cropland and others, the diversity index increased again (Figure 36). Relative MSDI and MSEI in each site across time is consistent, however, across landscapes, Viengkham, Manompana and East Usambara landscapes show much higher MSEI than the other two, indicating that composition of land-use and land-cover classes are much more even in the three landscapes, while Takamanda landscape is highly dominated by forest and Bungo by tree and forest cover (Figure 37).

The MSDI and MSEI in tandem with information on the dominant land-use and land-cover type can be used as a quick indication of landscape composition and the forest transition stage. Low MSDI and MSEI with forest domination suggest early stages of forest transition (Takamanda-Mone), while high MSDI shows a broad portfolio of land-use and land-cover types. In the case of uniform number of land-use and land-cover types under a general classification scheme, comparison across sites is not very useful but across time within a landscape is quite useful. In the case of Bungo, where the stage of forest transition has reached the turning point from the lowest forest and tree-cover fraction, the MSDI increases with forest as the dominant land-use and land-cover type until 1993 and then the MSDI decreases when tree cover took over as the dominant type in 1999. The MSEI shows a similar pattern except that it is normalised by the number of land-use and land-cover types. The landscapes of Viengkham, Manompana and East Usambara show increasing and very high MSEI over time, indicating that apart from forest, the extent of other land-use and land-cover types are very similar to each other, whilst those of Bungo are not.

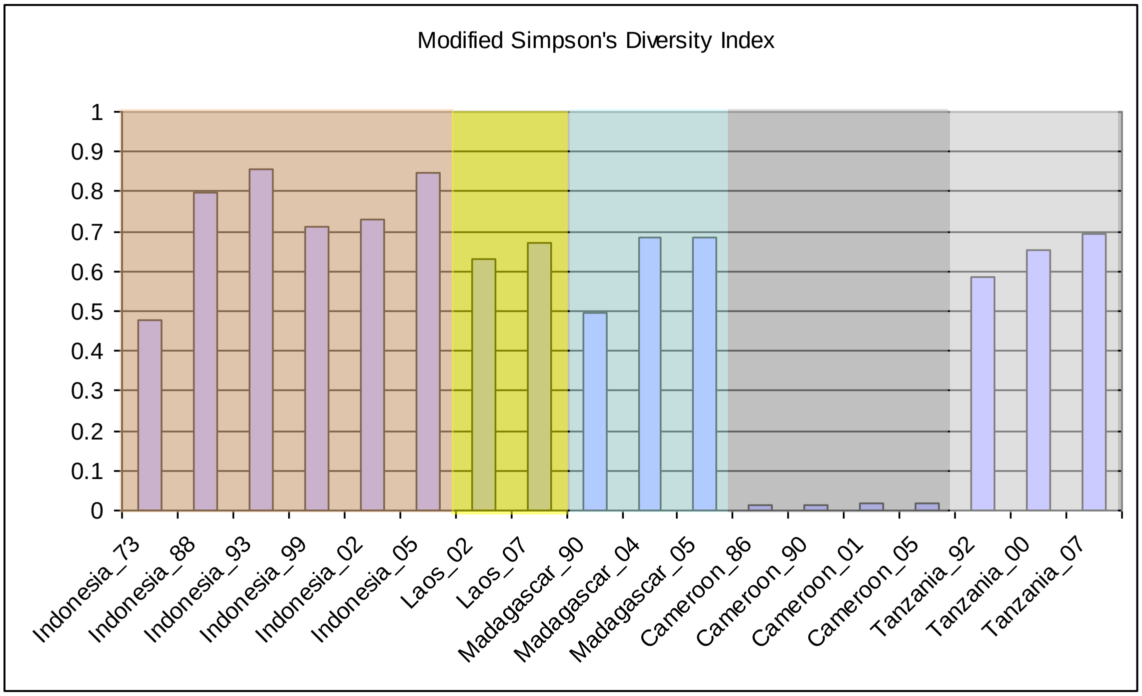

Figure 36. Modified Simpson's Diversity Index

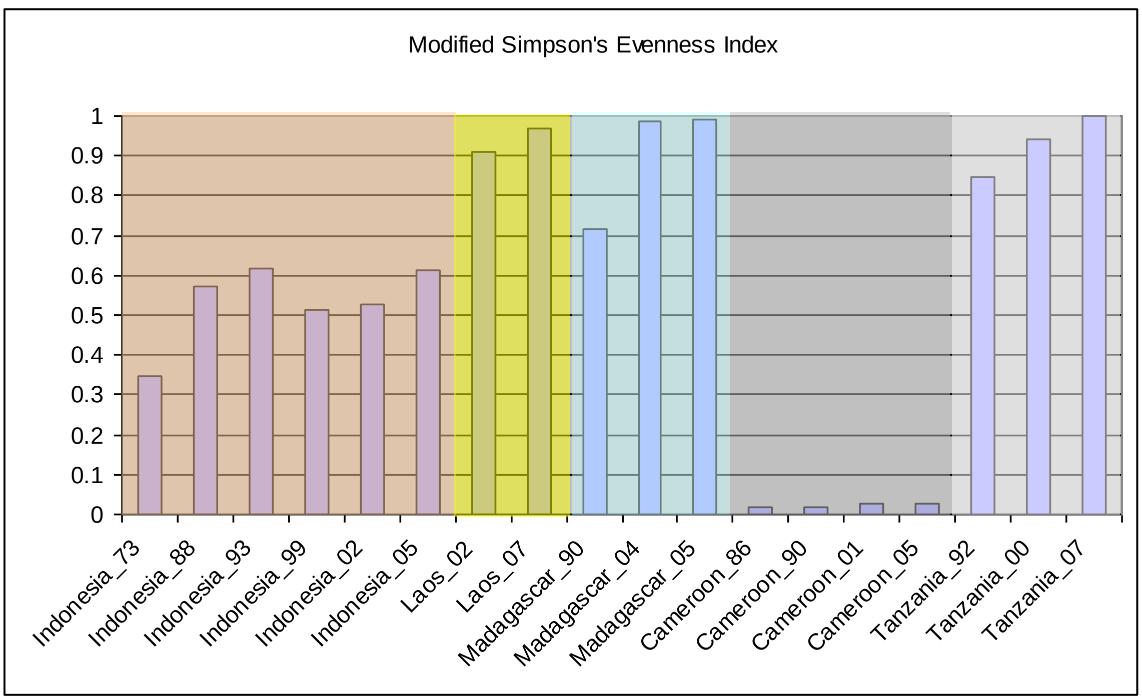

Figure 37. Modified Simpson's Evenness Index

Global landscape configuration

We selected three global landscape configuration indices to be presented and discussed here in regard to the relevance of our objectives and research questions. *Total area of forest* is relevant in terms of minimum habitat size of organisms, considering encroachment and invasion from the edge; *Aggregation Index* of forest is highly relevant since it shows how likely patches of forest are clumped together such that it reflects fragmentation of habitat, whilst the *Connectivity Index* of forest captures the likelihood of other forest patches to be found in a specified radius of a particular forest patch, even if they are not contiguous. This allows the roles of matrix (non-habitat) and the radius should be set specific to species based on dispersal ability. The two last indices are normalised such that comparison across landscapes can be done directly. Combination of the three indices should be able to capture some ecological processes that reflect biodiversity at the landscape level.

After a continuous sharp decline of total core forest area (in hectare) over time in Bungo landscape, at present it is comparable to those of Takamanda-Mone. However, in terms of proportion, Bungo total core area is much lower than Takamanda-Mone. While Bungo shows the sharpest decline in total core area, Manompana and East Usambara show comparable rates, and Takamanda-Mone shows a much slower rate. The Viengkham landscape shows increases in total core area, mostly owing to increases of tree cover, which reduces pressure of encroachment from the edge of the forest block, even though forest cover does not increase in extent.

The aggregation index is highest in Takamanda-Mone, followed by Bungo, showing the clumpiness of forest in the landscape. Manompana and East Usambara landscapes experience sharp declines in aggregation index over time, showing the rapid rate of fragmentation of existing primary forest blocks. The Viengkham landscape has a relatively low connectivity index despite high aggregation index showing that when not contiguous, forest patches located sparsely. These landscape-level indices and changes over time can be an early indication of the types of species that might be endangered. Species which are general in habitat requirement are less sensitive to the reduction of total core area, while specialists are prone to extinction with sharp and fast decreases in total core area. Species with high ability to migrate are not sensitive to reductions in aggregation given that this does not happen very rapidly, but those without that ability are prone to extinction. Widely dispersed propagules will allow species to survive even when connectivity is available at a relatively large radius but those that do not disperse widely will be prone to extinction with lower connectivity. In the East Usambara landscape, for example, specialist species will be threatened, as well as species that do not move across the landscape well and species that do not disperse well.

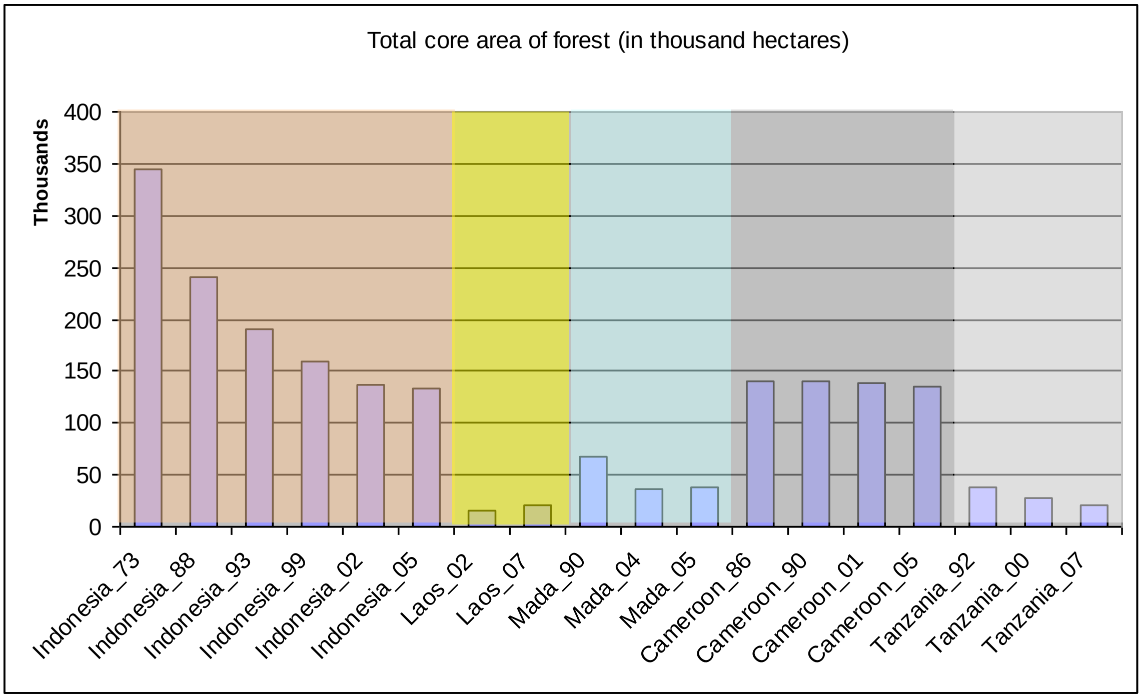

Figure 38. Total core area of forest in five sites over time

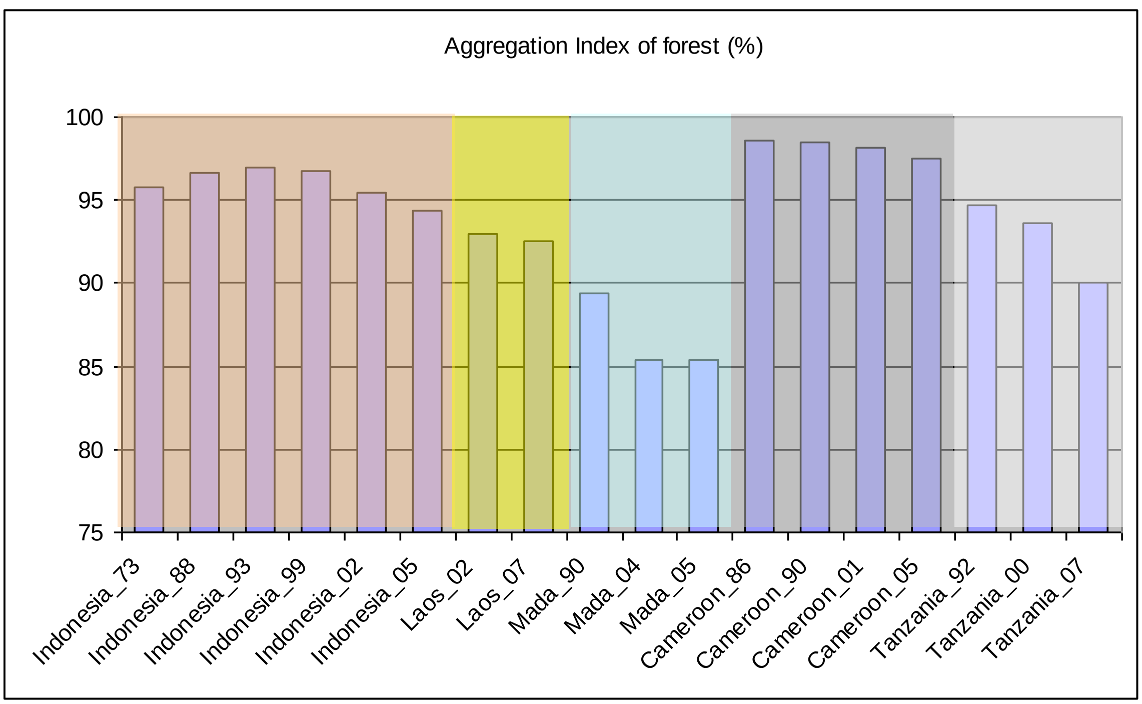

Figure 39. Aggregation index of forest in five sites over time

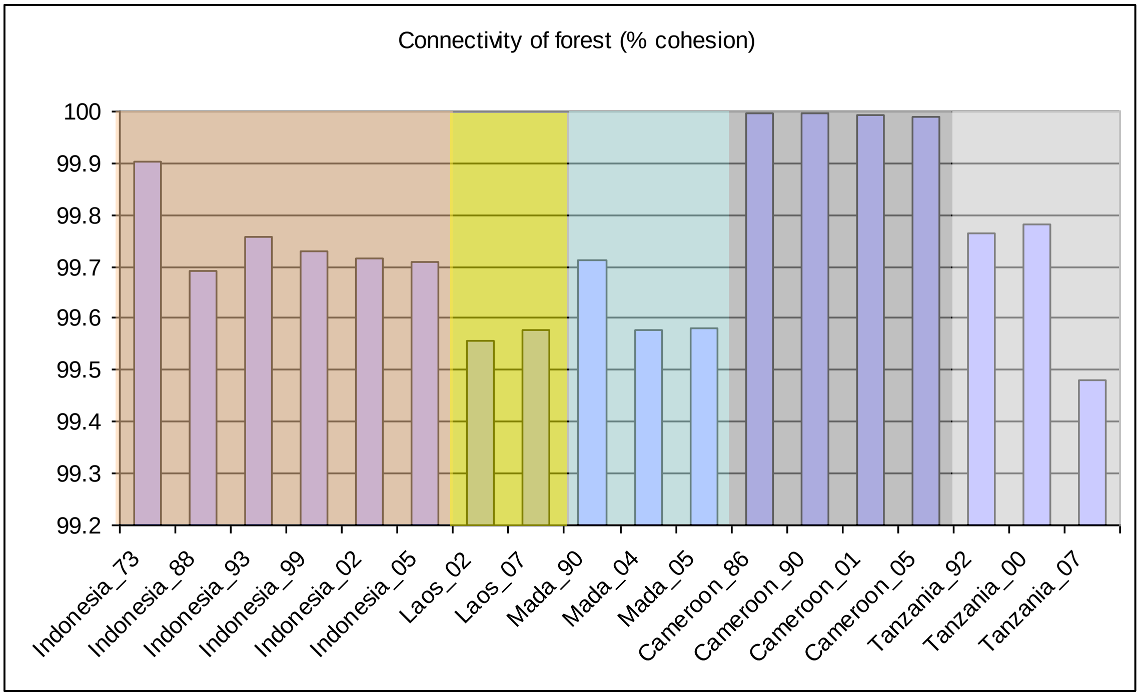

Figure 40. Connectivity index of forest in five sites over time

Landscape dynamics over space

This section will present visually the most current local (sub-landscape) configuration for each of the landscapes studied. Each pixel represents the indices for the circular area of 1 km radius from it. Please note that while some aggregation index maps often look similar to connectivity maps, it is not always the case, especially when forest is surrounded by land cover dissimilar to forest, that is, settlements, non-vegetation and non-tree-based systems. When forest patches are often found in the surrounds of tree-based patches without being contiguous then connectivity is markedly different from aggregation, that is, connectivity is much higher than aggregation.

This local (sub-landscape) analysis will be useful in terms of identifying the critical area where non-connectivity of two large blocks of forest is bound to happen and, therefore, intervention could be endorsed. These visualisations should help in visioning, focus group discussions and communicating messages to the public and policy makers, especially in light of land-use planning to reconcile livelihoods options and biodiversity maintenance at local and landscape levels. Several guidelines, criteria and indicators can be negotiated among multiple stakeholders to reconcile local ecological knowledge, scientific perspectives and current policies and customary laws, as outlined below.

1. High total core forest area should be under some measures of protection, otherwise, if there are settlements close by then some awareness raising and contracts or agreements between government and the local people should be developed.
2. Areas surrounding a large forest core area with high aggregation index should be tagged as priority areas for rehabilitation if located inside protected areas or conserved under some

mechanism of rewards for environmental services if located outside protected areas with some inhabitants or minimum management, for example, under a Village Forest contract. Highly aggregated forest outside total core forest areas and outside protected areas with no human presence should be delineated as protected areas.

3. Areas surrounding a large forest core area with high connectivity index should be tagged as priority areas for rehabilitation if located inside protected areas or (re)-planted and managed under low intensification of land uses with trees of economic values, for example, rubber agroforestry, if located outside protected areas with some local communities.
4. Areas that are none of the above but identified as critical in connecting pieces of primary forest blocks under potentially low costs or hotspots of endemic species or particular environmental services should be delineated as priority areas for agroforestry or other low-intensity tree systems or forest under co-investment schemes between local communities and other stakeholders

Indicative areas of each above point for each landscape are shown in Figures 41–55. If there are specific concerns for endangered species, such maps can be used as tools to delineate specific habitat and threat so that measures of protection can be determined.

Indonesia (Bungo)

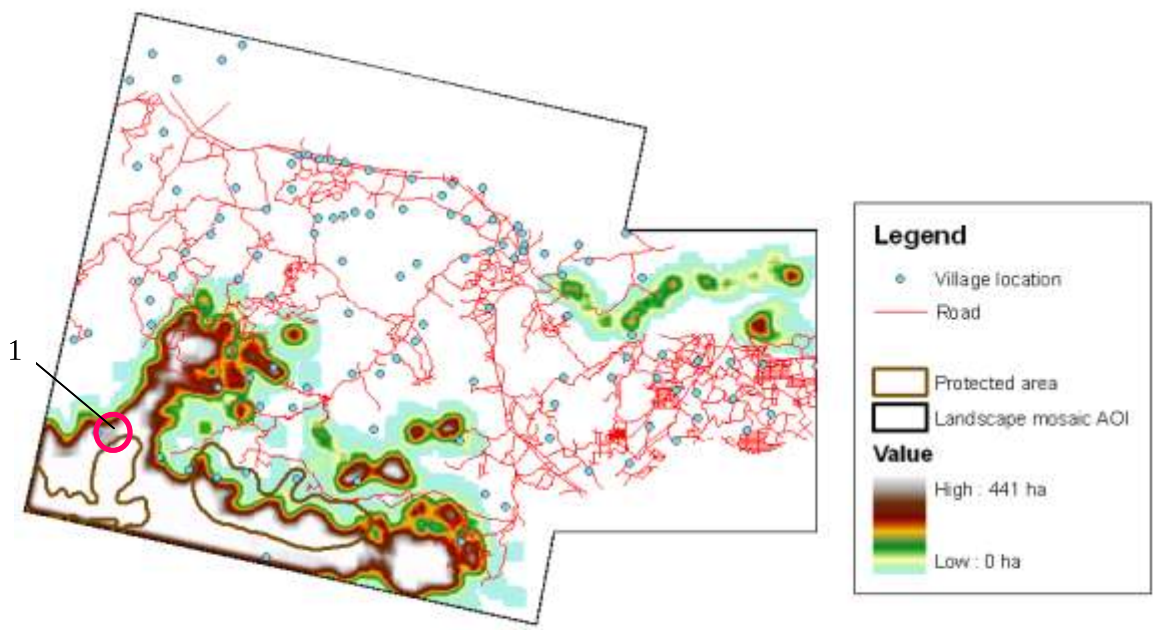

Figure 41. Current total core area of forest (0–441 ha) of Bungo, Indonesia

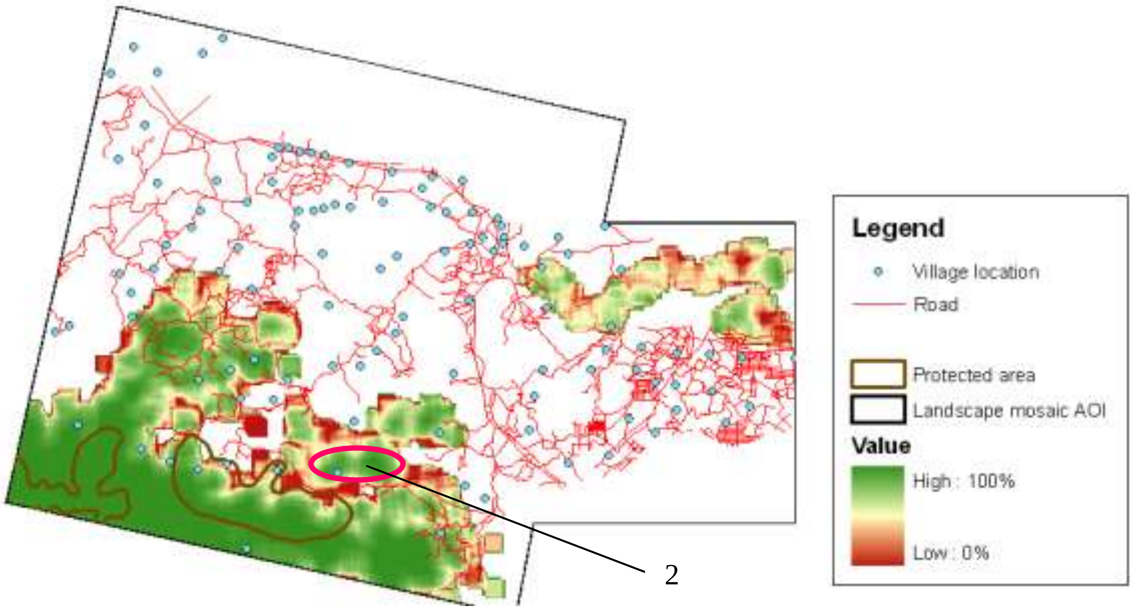

Figure 42. Current forest aggregation index (0–100%) of Bungo, Indonesia

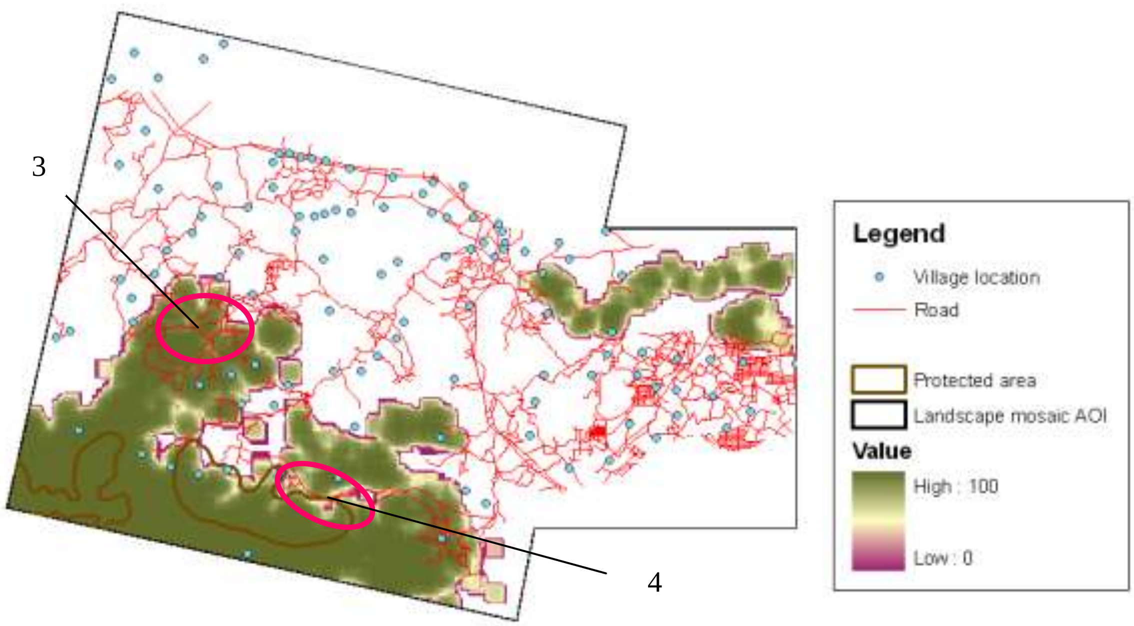

Figure 43. Current connectivity of forest (0–100%) of Bungo, Indonesia

Lao PDR (Viengkham)

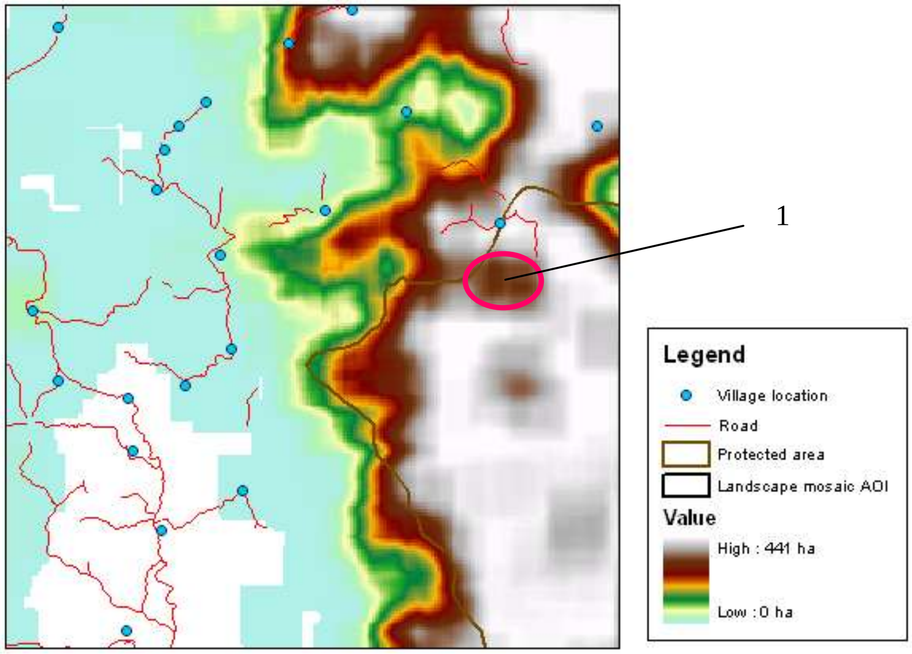

Figure 44. Current total core area of forest (0–441 ha) of Viengkham, Lao PDR

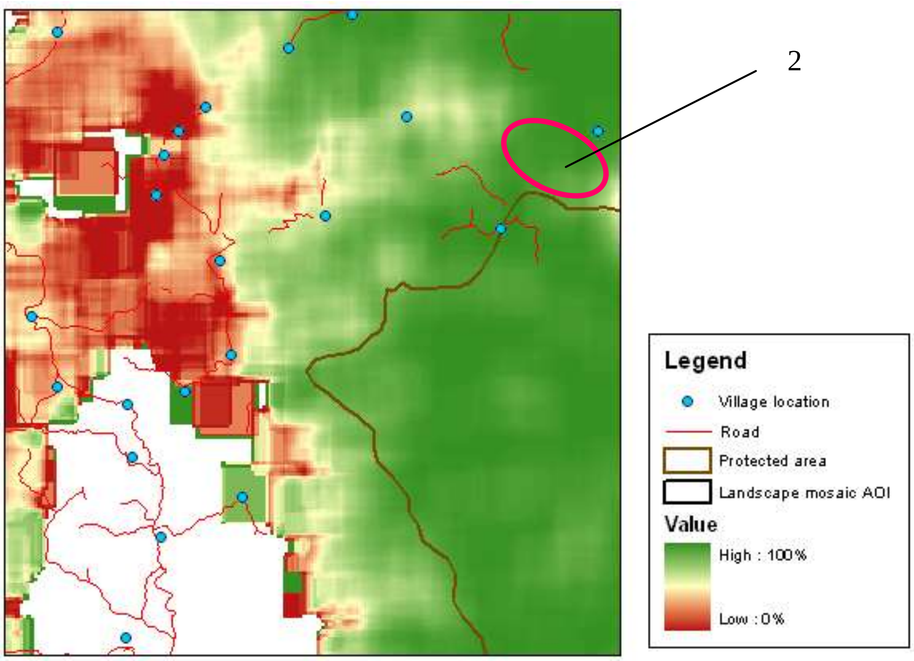

Figure 45. Current forest aggregation index (0–100%) of Viengkham, Lao PDR

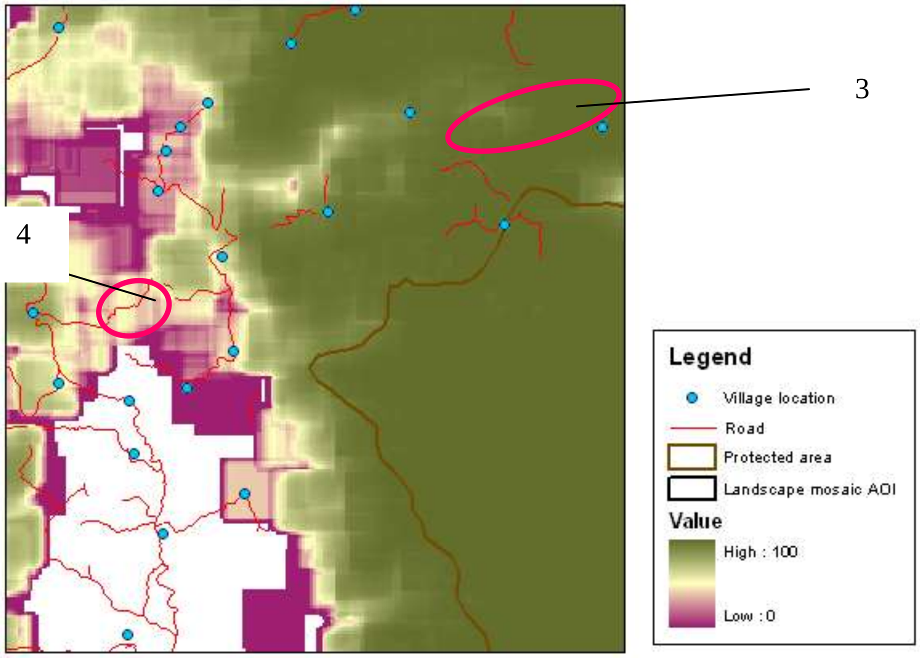

Figure 46. Current connectivity of forest (0–100) of Viengkham, Lao PDR

Madagascar (Manompana)

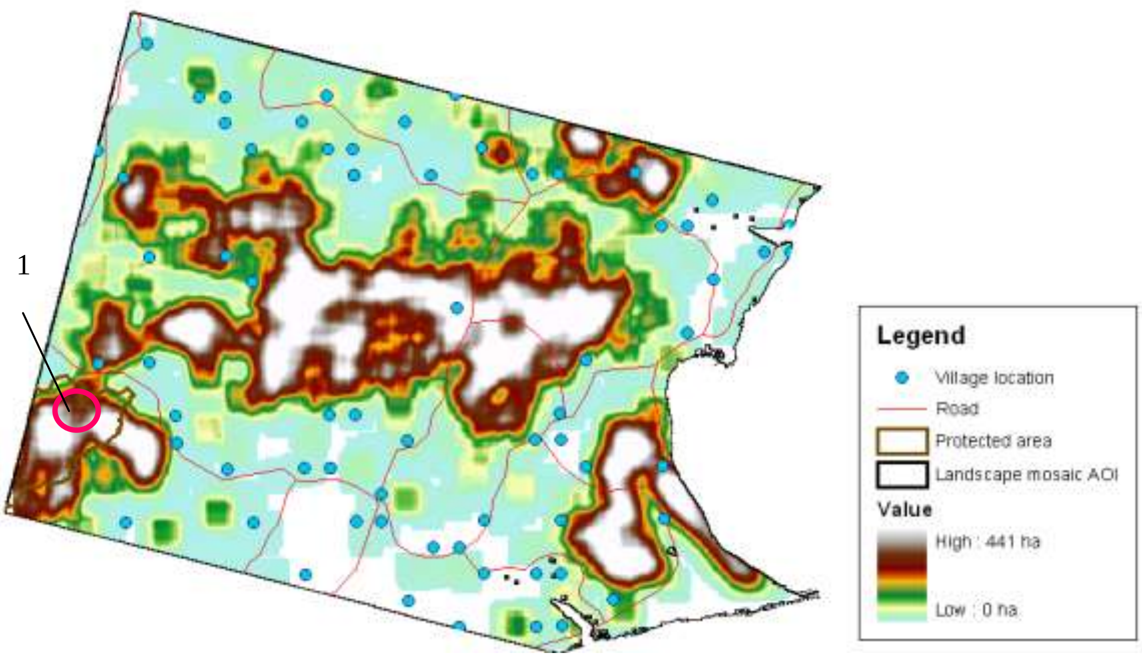

Figure 47. Current total core area of forest (0–441 ha) of Manompana, Madagascar

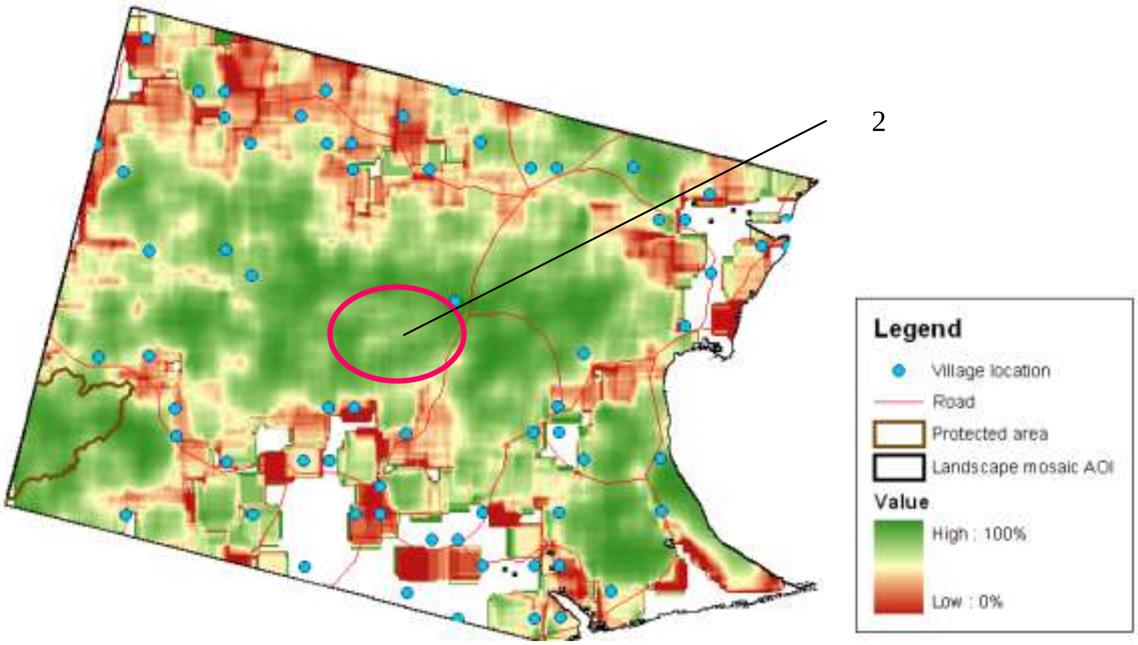

Figure 48. Current forest aggregation index (0–100%) of Manompana, Madagascar

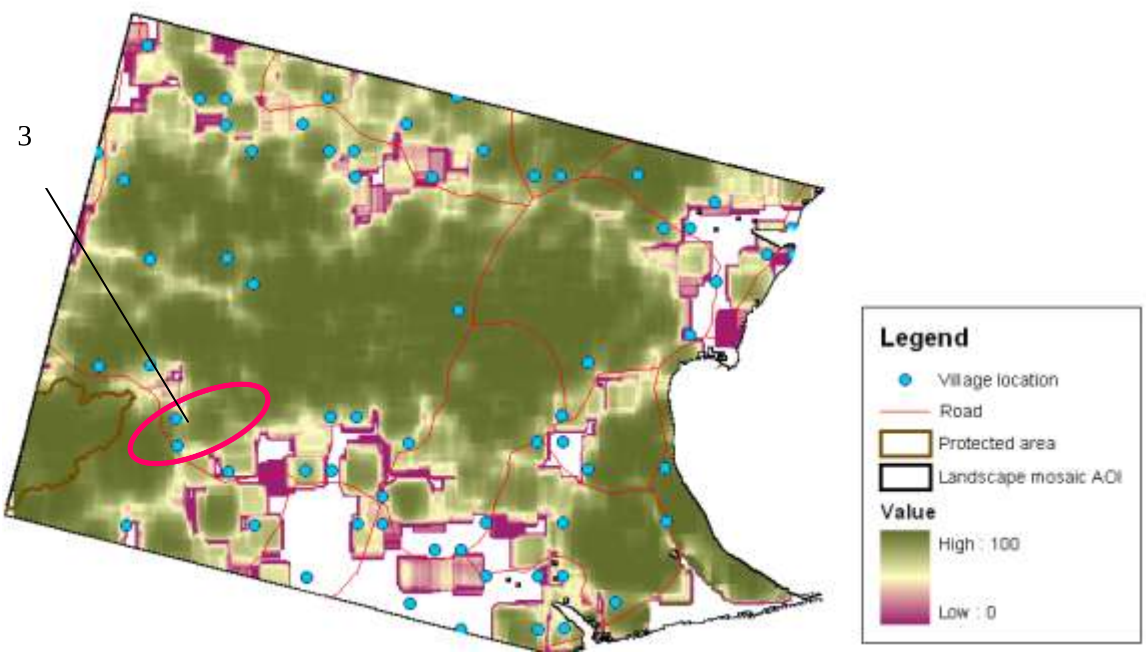

Figure 49. Current connectivity of forest (0–100) of Manompana, Madagascar

Cameroon (Takamanda-Mone)

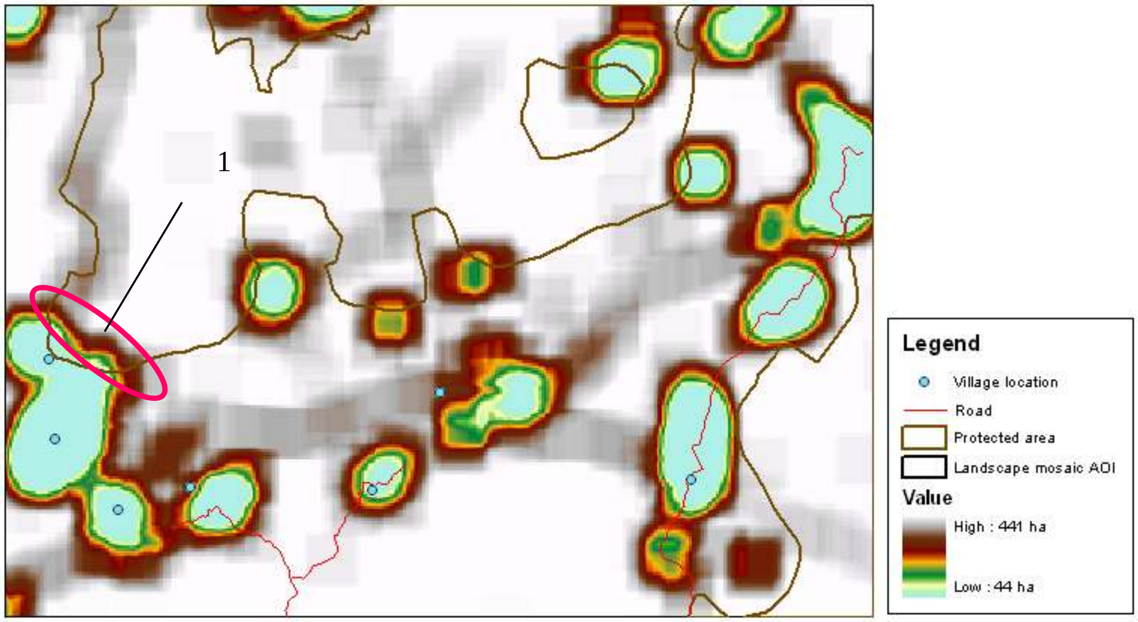

Figure 50. Current total core area of forest (0–441 ha) of Takamanda-Mone, Cameroon

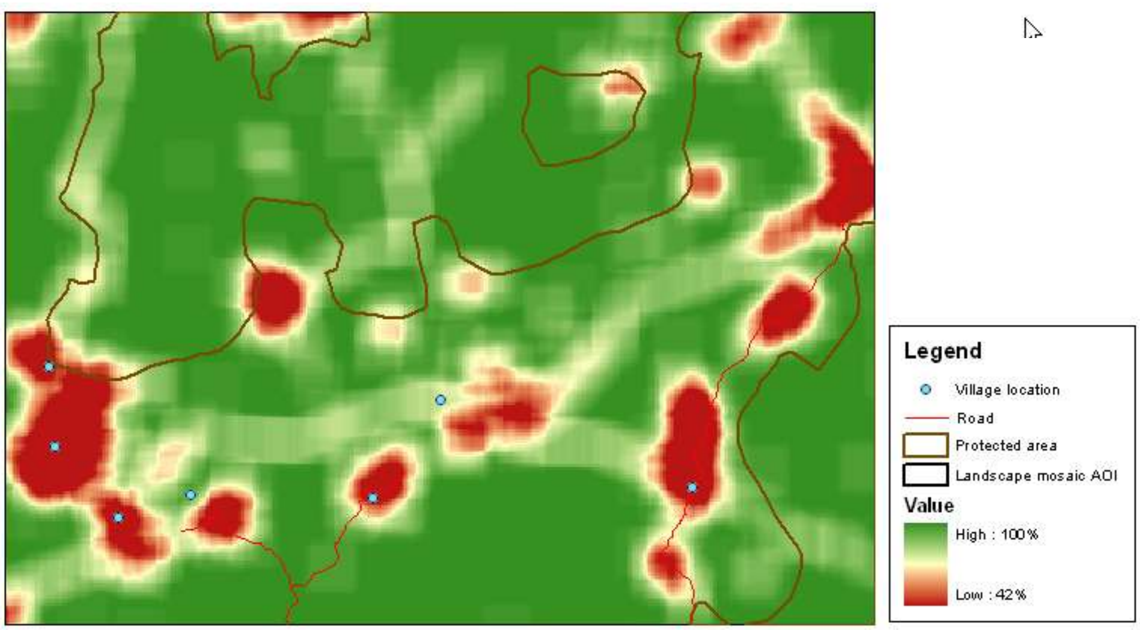

Figure 51. Current forest aggregation index (0–100%) of Takamanda-Mone, Cameroon

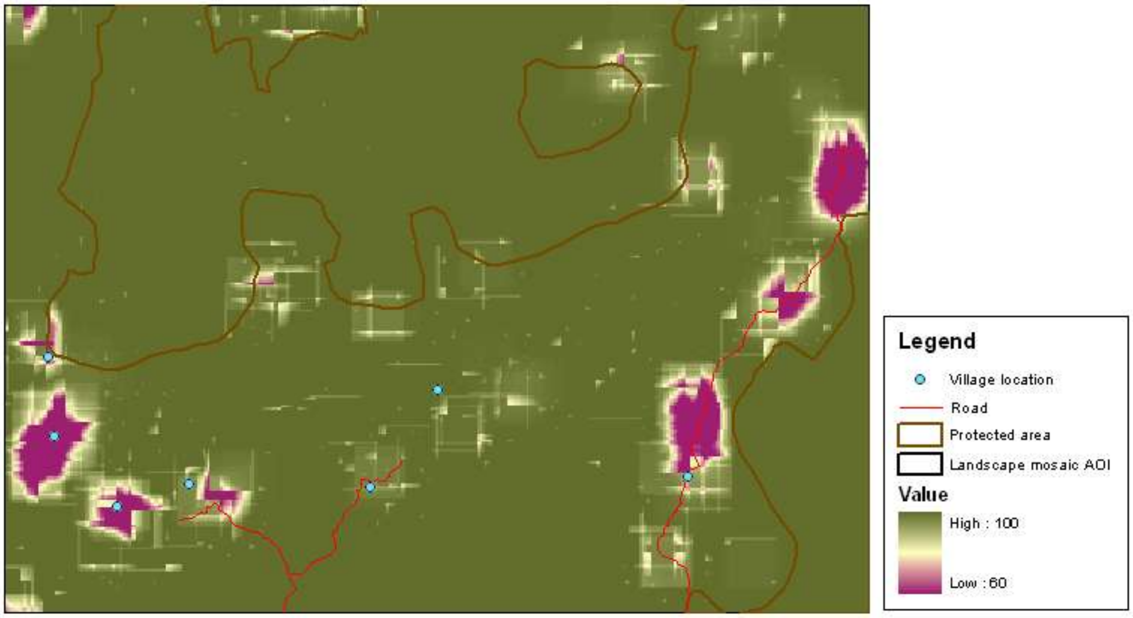

Figure 52. Current connectivity of forest (0–100) of Takamanda-Mone, Cameroon

Tanzania (East Usambara)

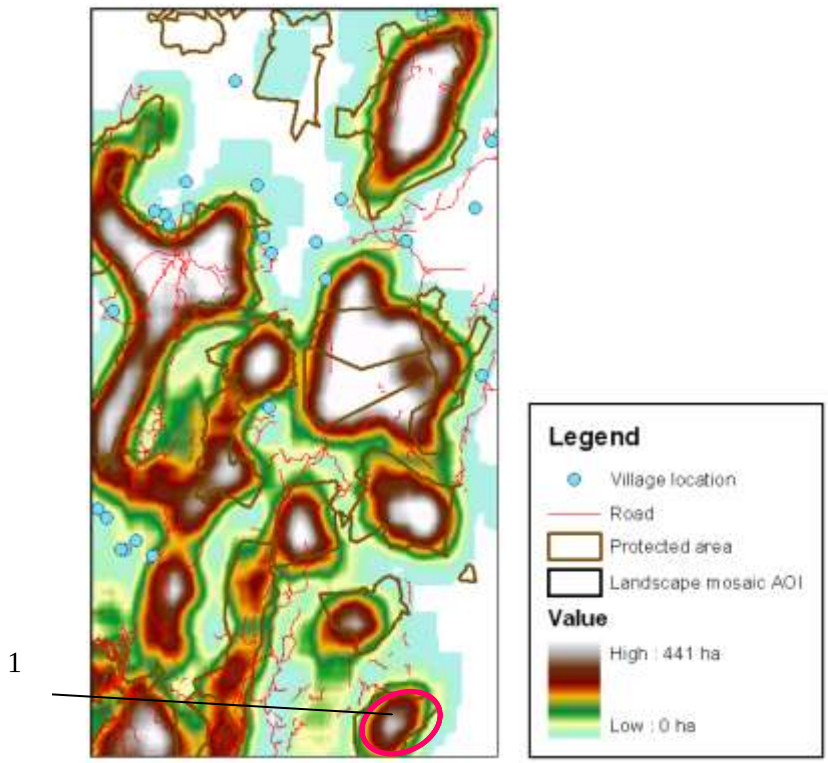

Figure 53. Current total core area of forest (0–441 ha) of East Usambara, Tanzania

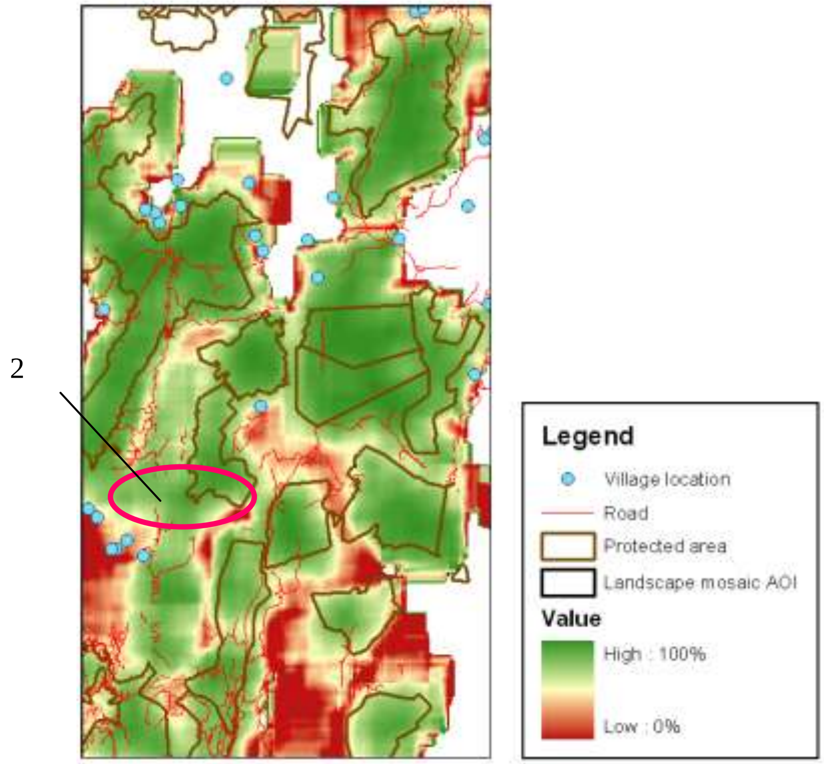

Figure 54. Current forest aggregation index (0–100%) of East Usambara, Tanzania

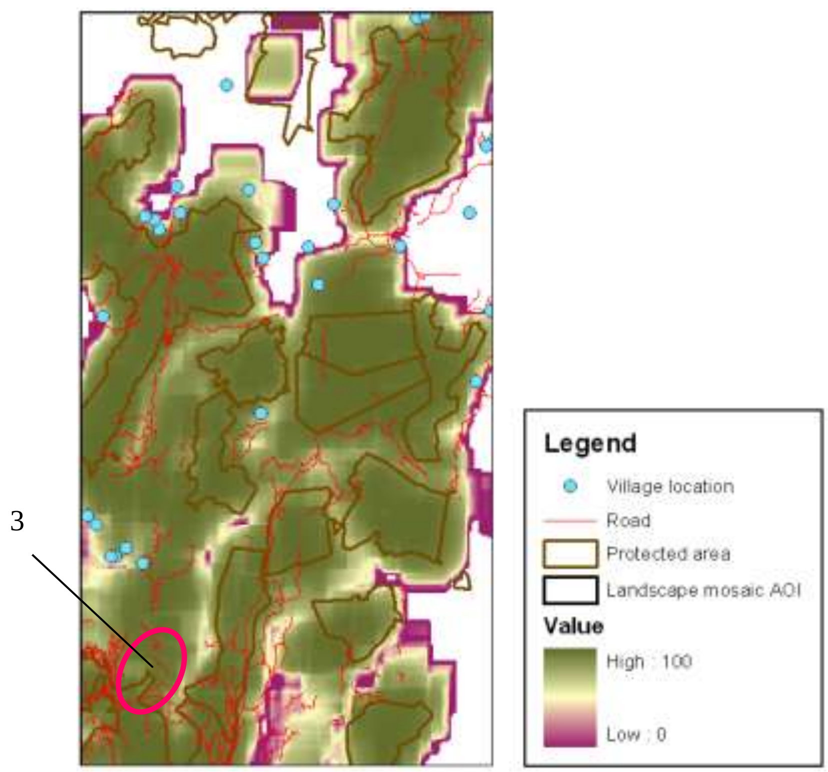

Figure 55. Current connectivity of forest (0–100) of East Usambara, Tanzania

Landscape dynamics over time and space

In this section we will visualise changes in local (sub-landscape) configuration over time at the five sites. These analyses should be useful in projecting the future total core area, aggregation and also connectivity based on past changes. Beyond that, areas that are prone to dis-aggregation/fragmentation and non-connectivity/isolation can be identified.

By combining these analyses with scenarios to project the future land-use and land-cover changes, we will able to provide an effective 'negotiation' platform with multi-stakeholders by showing the 'what if' situation. Showing the areas that are most likely to be isolated or fragmented under particular scenarios within such and such years is a powerful way to start a discussion on land-use planning.

Some guidelines, criteria and indicators to be used in the land-use planning process could be derived, as discussed below.

- Delineating the likely loss of total forest core area based on the previous pattern of deforestation, for example, in Bungo (Figure 56), Monampana (Figure 62) and East Usambara (Figure 68) cases, deforestation mainly happened as encroachment from the edge of the primary forest block, while in Viengkham (Figure 59) and Takamanda-Mone (Figure 65) deforestation predominantly takes place along the new road and the river. Apart from that, settlements in the middle of primary forest blocks continue to expand.
- Identification of the likely loss of areas with high aggregation index surrounding large primary forest blocks (Figures 57, 60, 63, 66, 69).
- Identification of the likely loss of areas with connectivity index surrounding large primary forest blocks (Figures 58, 61, 64, 67, 70).

In addition to the past spatial pattern of deforestation, the likelihood or probability of deforestation and land-use and land-cover changes can be derived from multi-agent modelling, empirical modelling or spatially explicit driver modelling. Further, the projections or predictions can be used as a layer of information to be incorporated in identification of vulnerable areas of habitat loss, increased fragmentation and reduced connectivity. Negotiation and protection measures could be established in these vulnerable areas along with other interventions. Trade-offs between conservation and development should be sought, for example, identifying areas of low opportunity cost (from cost-benefit analyses of land-use systems) with high conservation values.

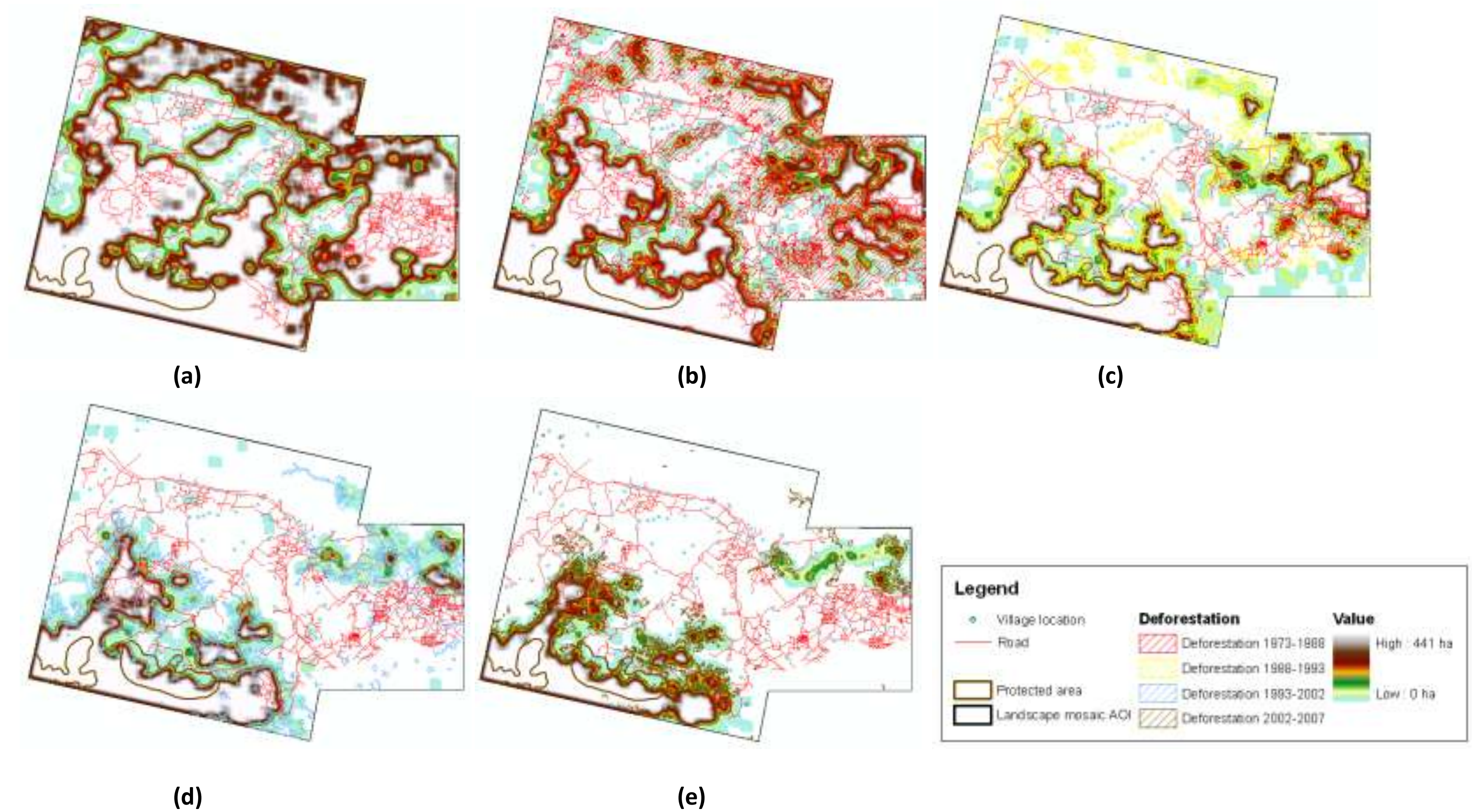

Figure 56. Time series of total core area of forest: (a) total core area in 1973; (b) total core area in 1988 with deforestation in 1973–1988; (c) total core area in 1993 with deforestation in 1988–1993; (d) total core area in 2002 with deforestation in 1993–2002; (e) total core area in 2007 with deforestation in 2002–2007

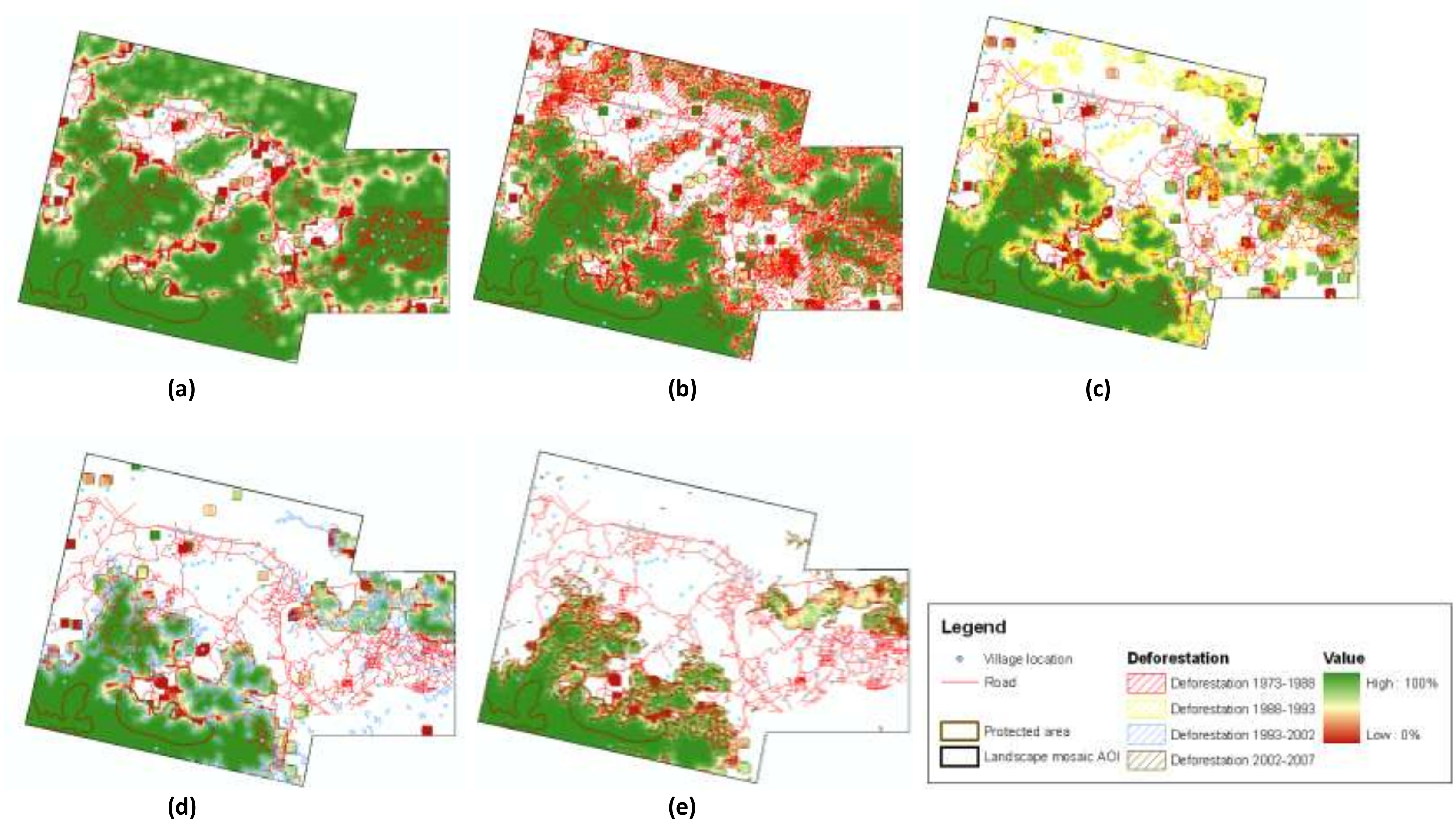

Figure 57. Time series of aggregation index of forest: (a) aggregation index in 1973; (b) aggregation index in 1988 with deforestation in 1973–1988; (c)aggregation index in 1993 with deforestation in 1988–1993; (d) aggregation index in 2002 with deforestation in 1993–2002; (e) aggregation index in 2007 with deforestation in 2002–2007

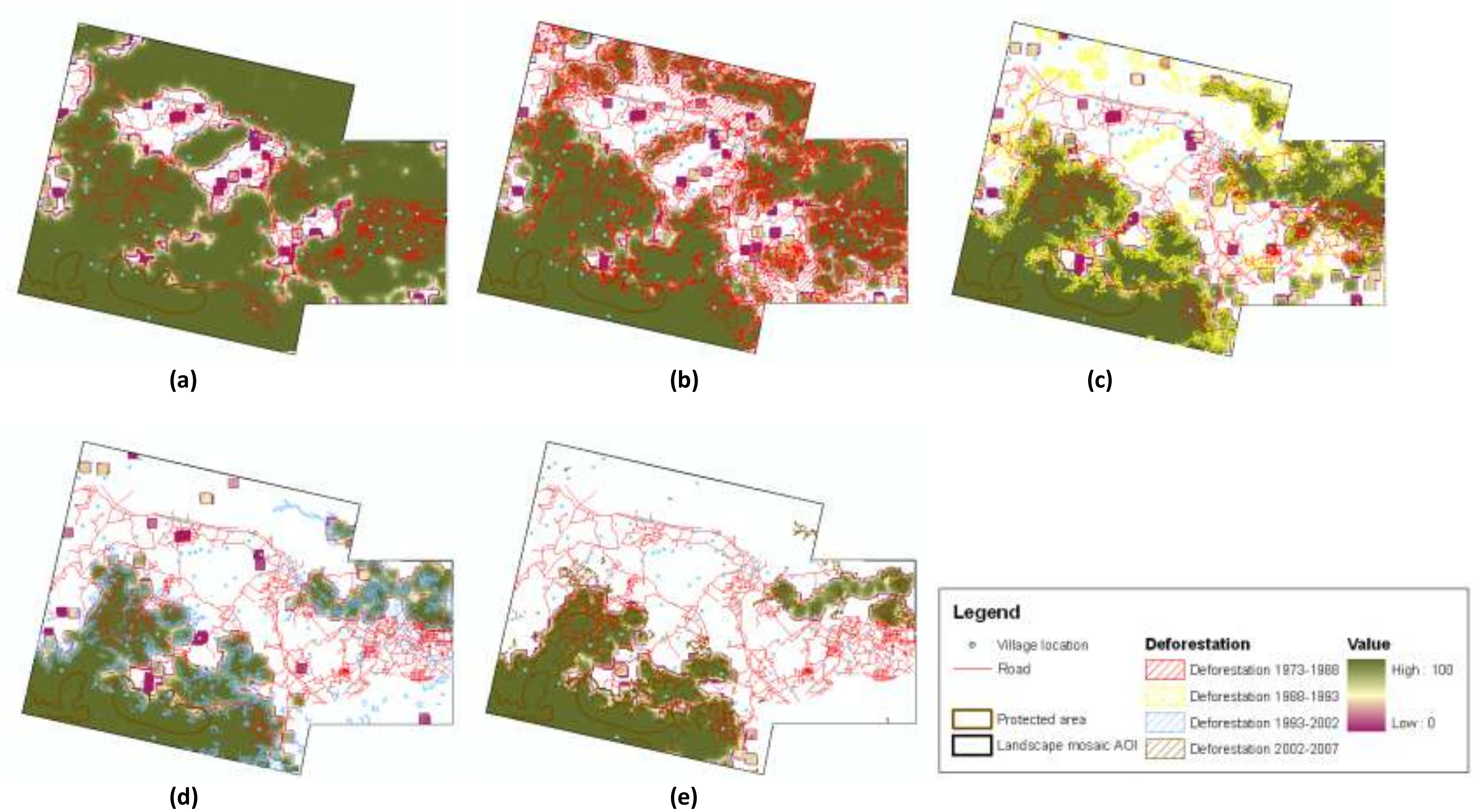

Figure 58. Time series of connectivity of forest: (a) connectivity in 1973; (b) connectivity in 1988 with deforestation in 1973–1988; (c) connectivity in 1993 with deforestation in 1988–1993; (d) connectivity in 2002 with deforestation in 1993–2002; (e) connectivity in 2007 with deforestation in 2002–2007

Laos (Viengkham)

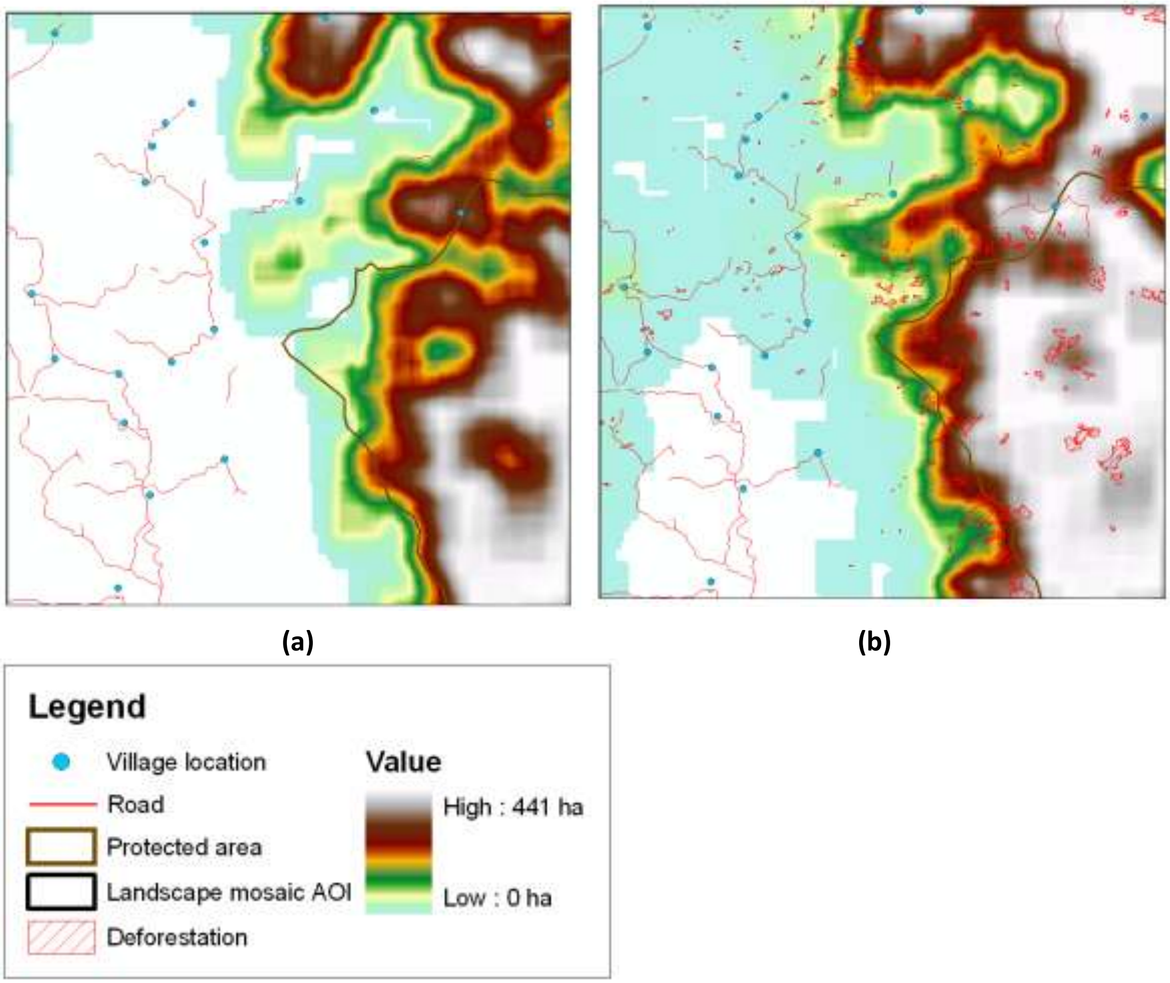

Figure 59. Time series of total core area of forest: (a) total core area in 2002; (b) total core area in 2007 with deforestation 2002–2007

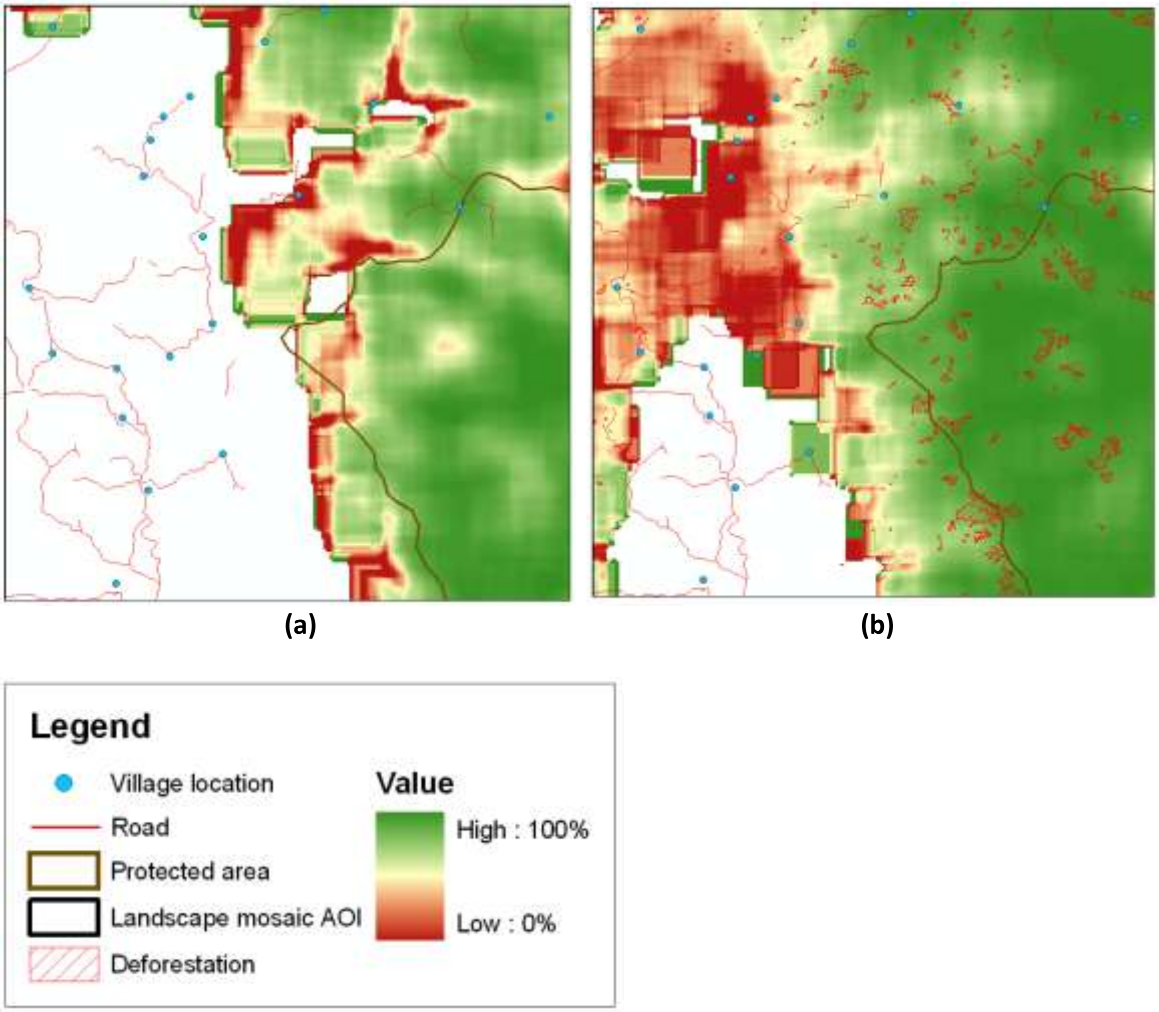

Figure 60. Time series of aggregation index of forest: (a) aggregation index in 2002; (b) aggregation index in 2007 with deforestation 2002–2007

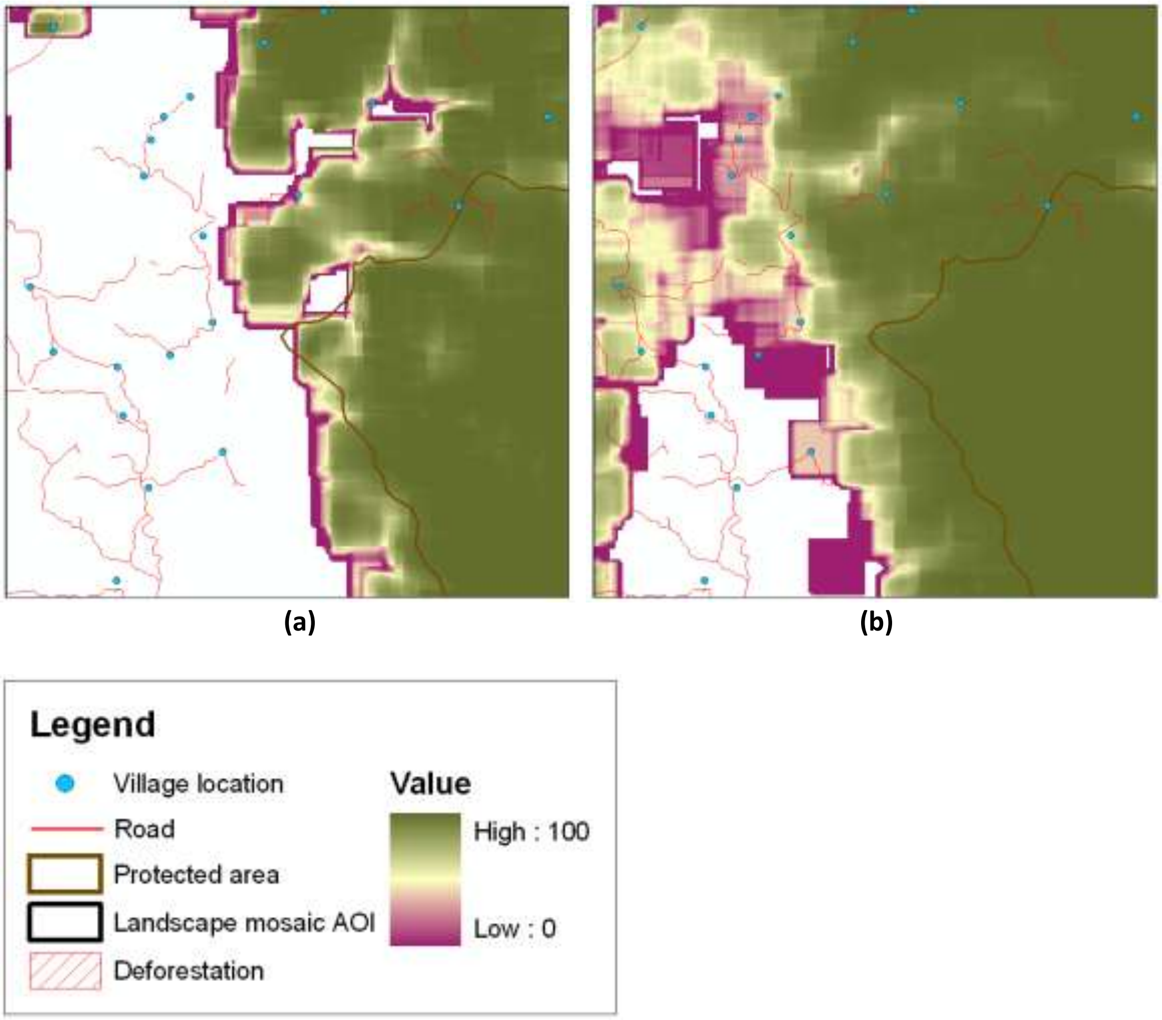

Figure 61. Time series of connectivity of forest: (a) connectivity in 2002; (b) connectivity in 2007 with deforestation 2002–2007

Madagascar (Manompana)

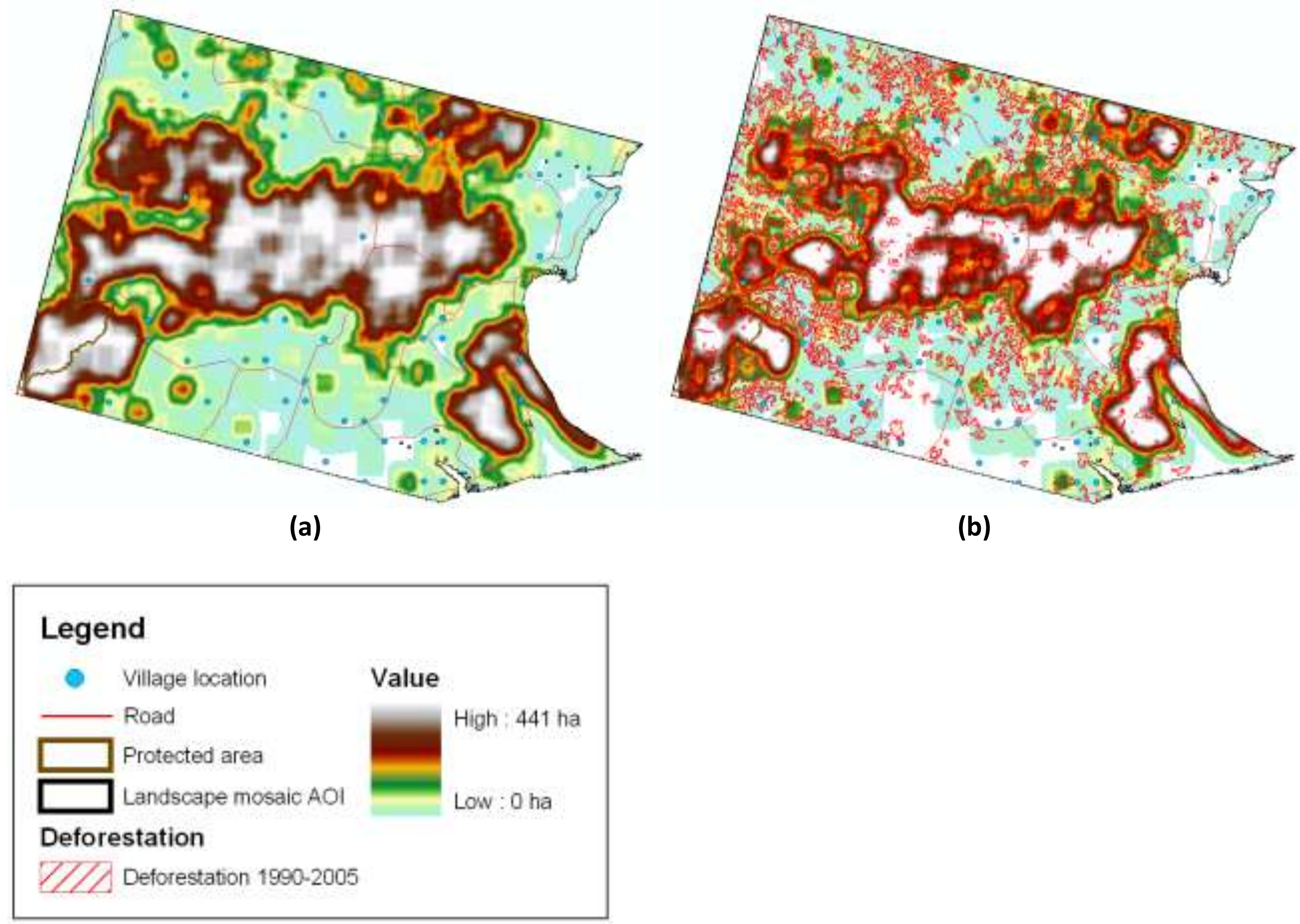

Figure 62. Time series of total core area of forest: (a) total core area in 1990; (b) total core area in 2005 with deforestation1990–2005

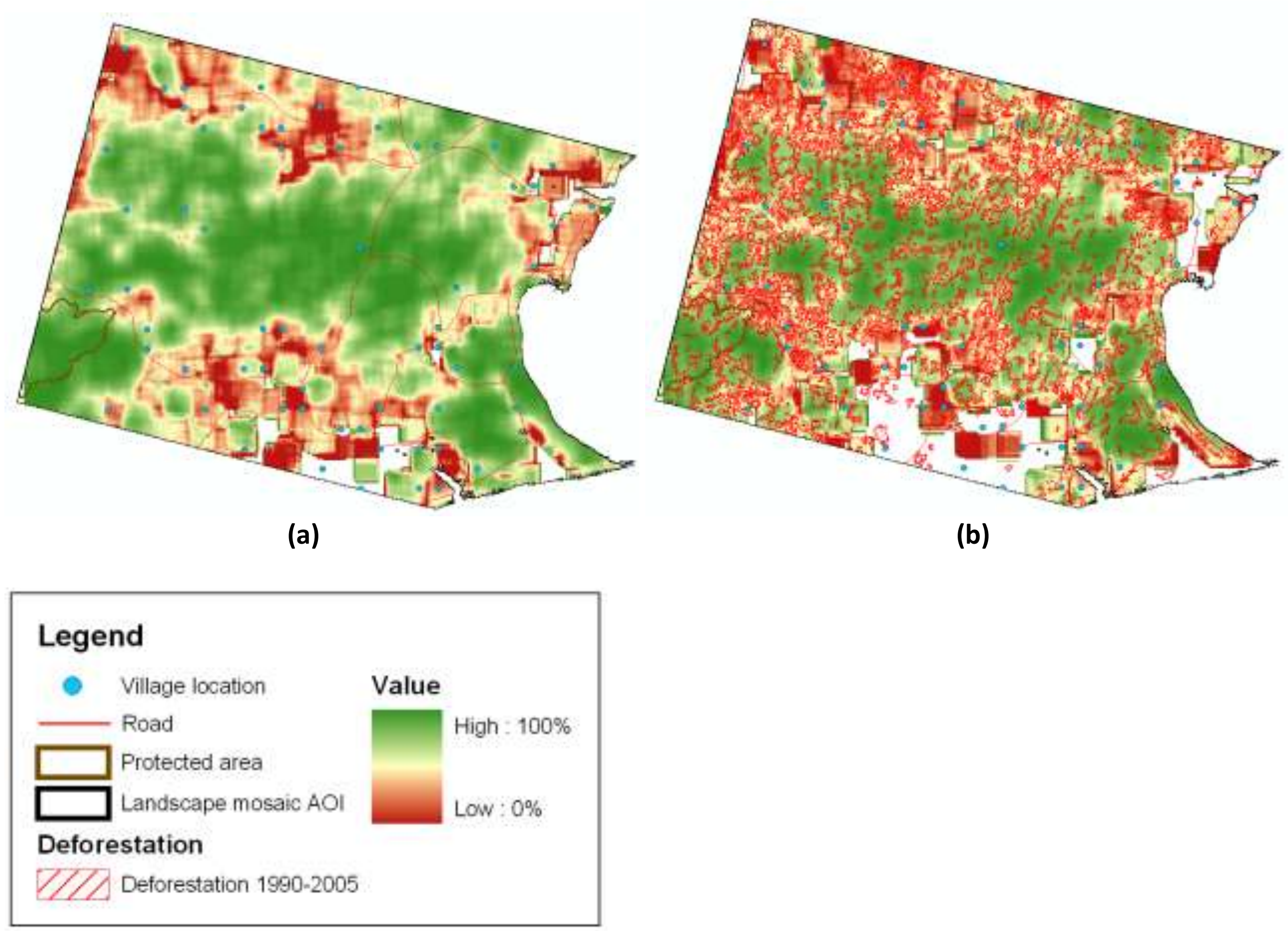

Figure 63. Time series of aggregation index forest: (a) aggregation index in 1990; (b) aggregation index in 2005 with deforestation 1990–2005

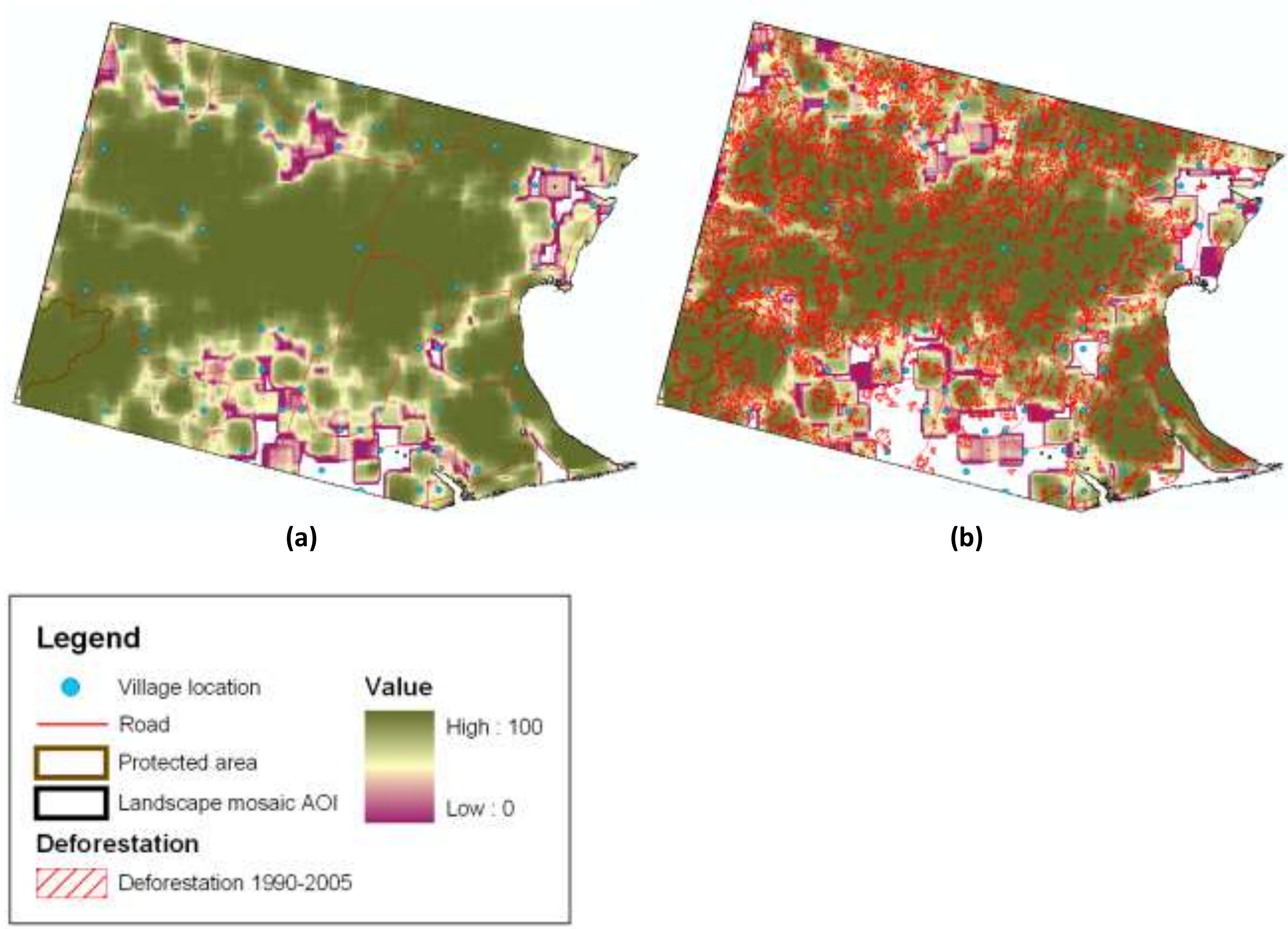

Figure 64. Time series of connectivity of forest: (a) connectivity in 1990; (b)connectivity in 2005 with deforestation 1990–2005

Cameroon (Takamanda-Mone)

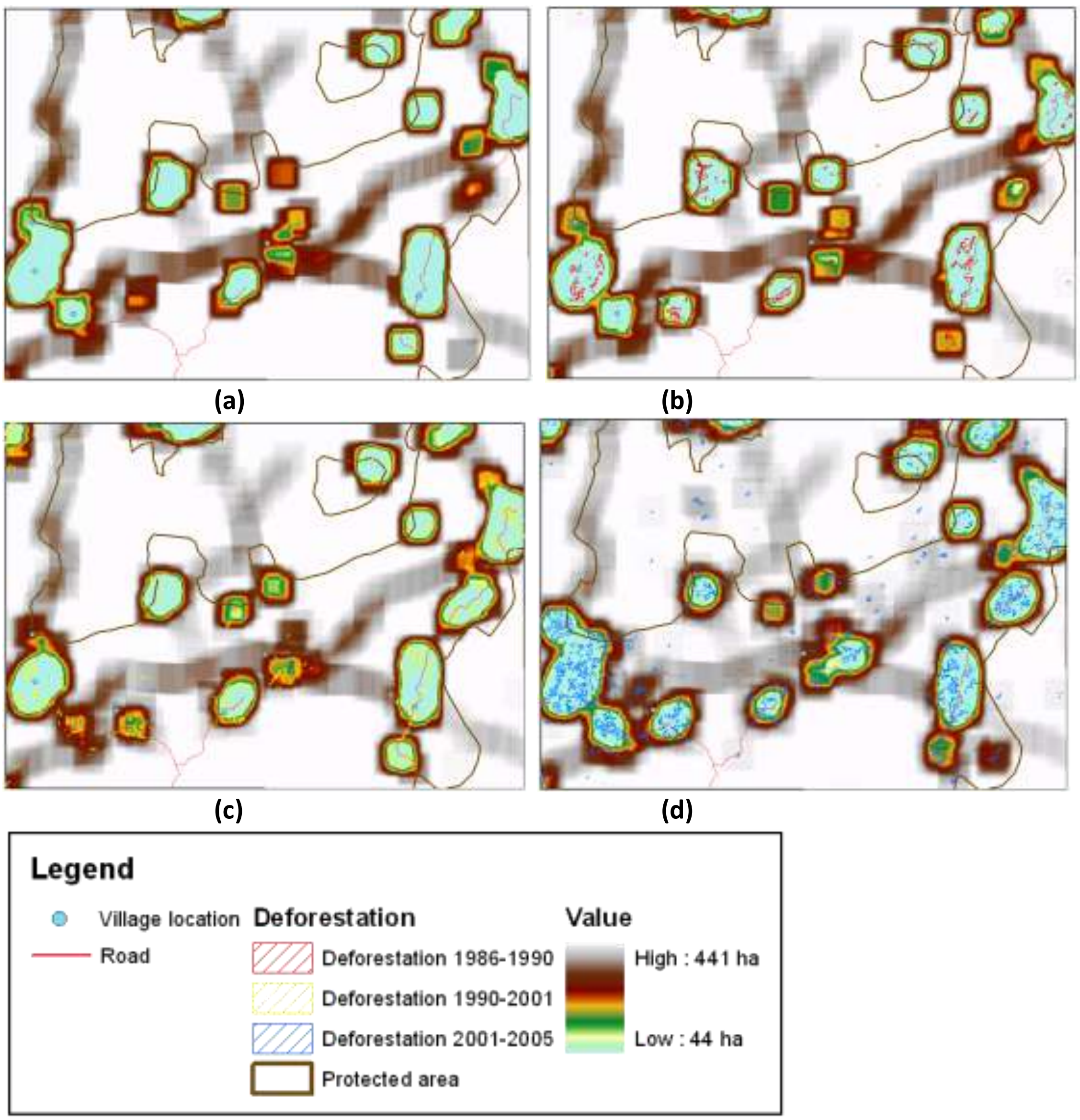

Figure 65. Time series of total core area of forest: (a) total core area in 1986; (b) total core area in 1990 with deforestation in 1986–1990; (c) total core area in 2001 with deforestation in 1990–2001; (d) total core area in 2005 with deforestation in 2001–2005

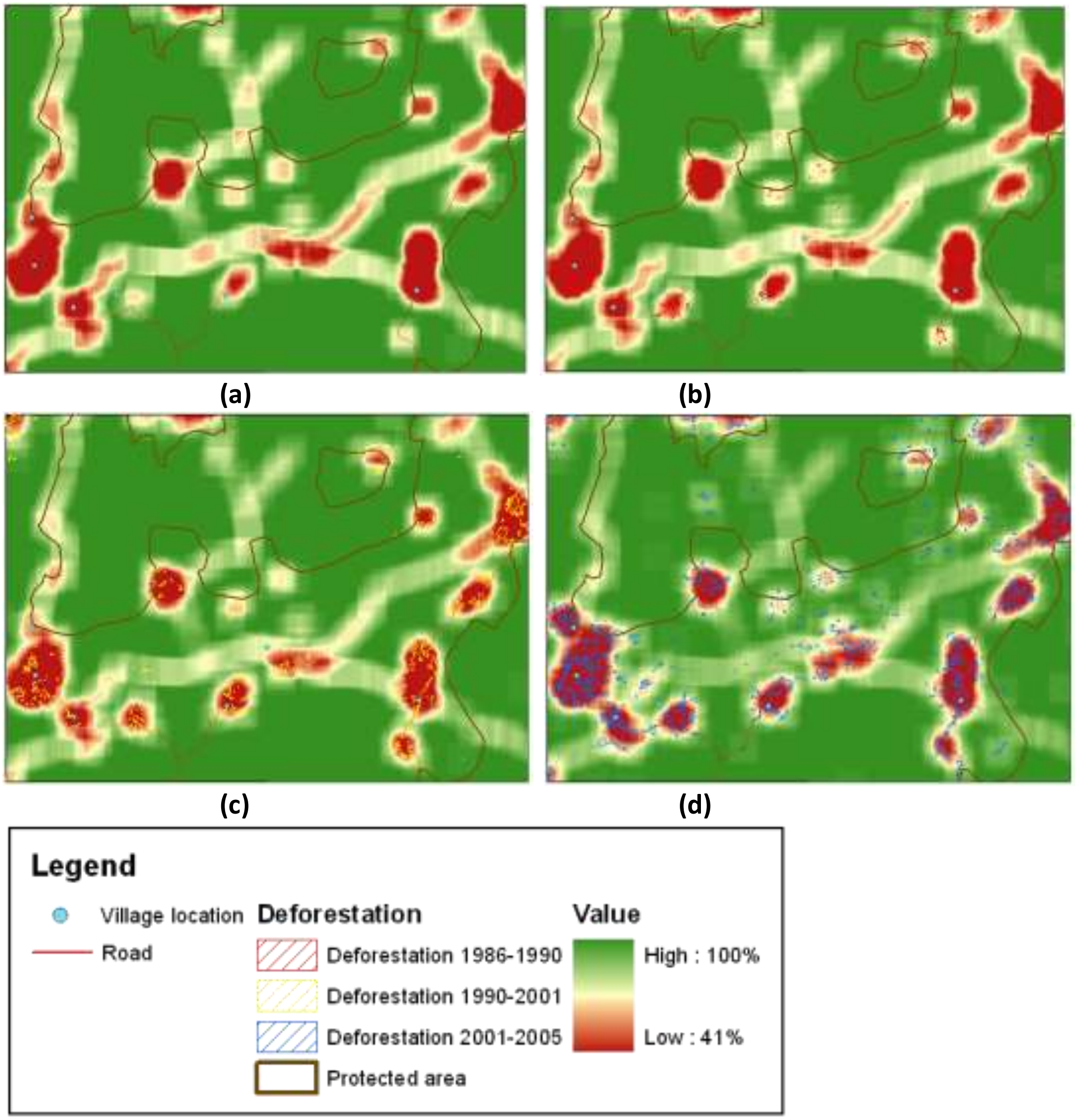

Figure 66. Time series of aggregation index of forest: (a) aggregation index in 1986; (b) aggregation index in 1990 with deforestation in 1986–1990; (c) aggregation index in 2001 with deforestation in 1990–2001; (d) aggregation index in 2005 with deforestation in 2001–2005

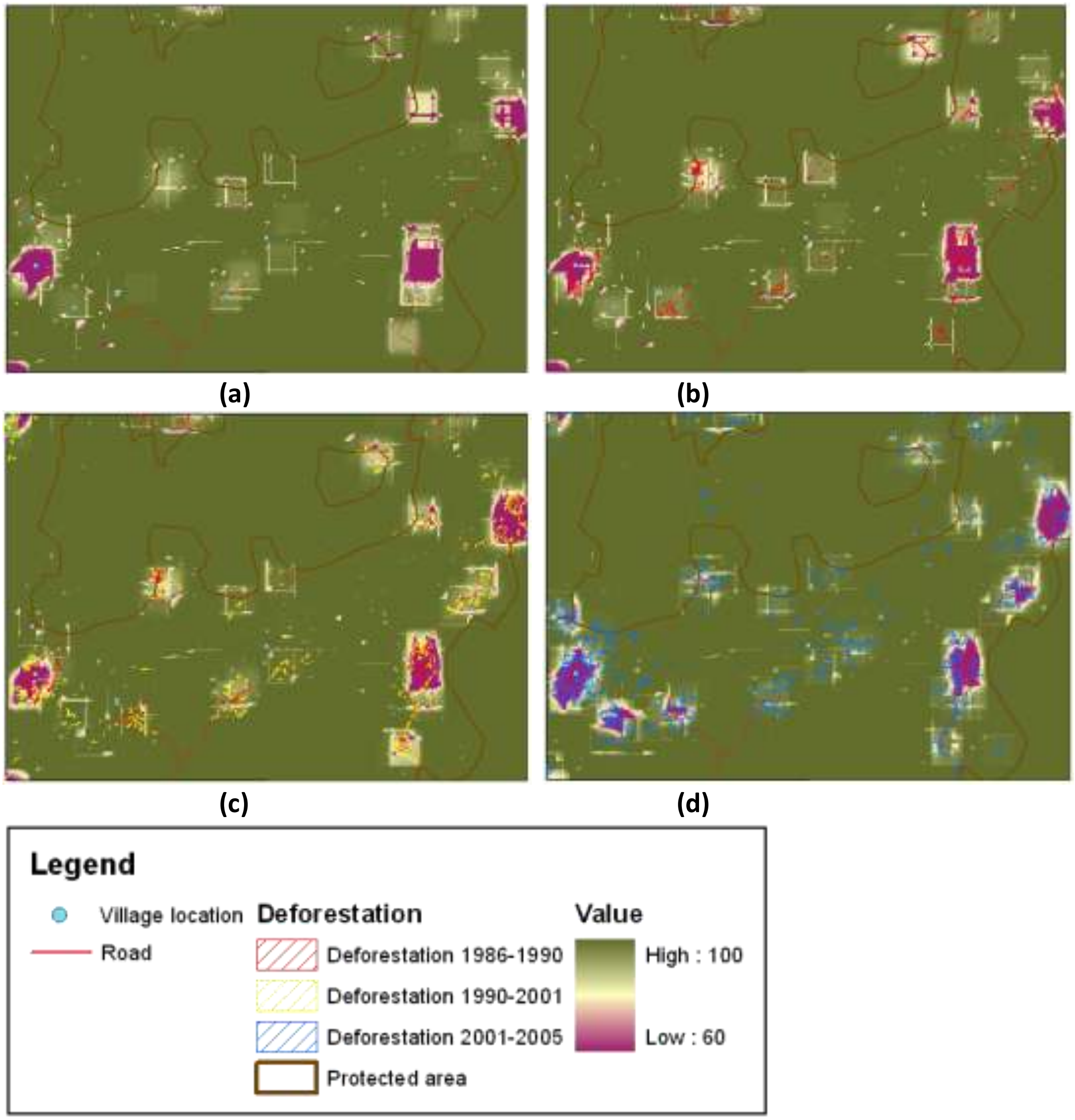

Figure 67. Time series of connectivity of forest: (a) connectivity in 1986; (b) connectivity in 1990 with deforestation in 1986–1990; (c) connectivity in 2001 with deforestation in 1990–2001; (d) connectivity in 2005 with deforestation in 2001–2005

Tanzania (East Usambara)

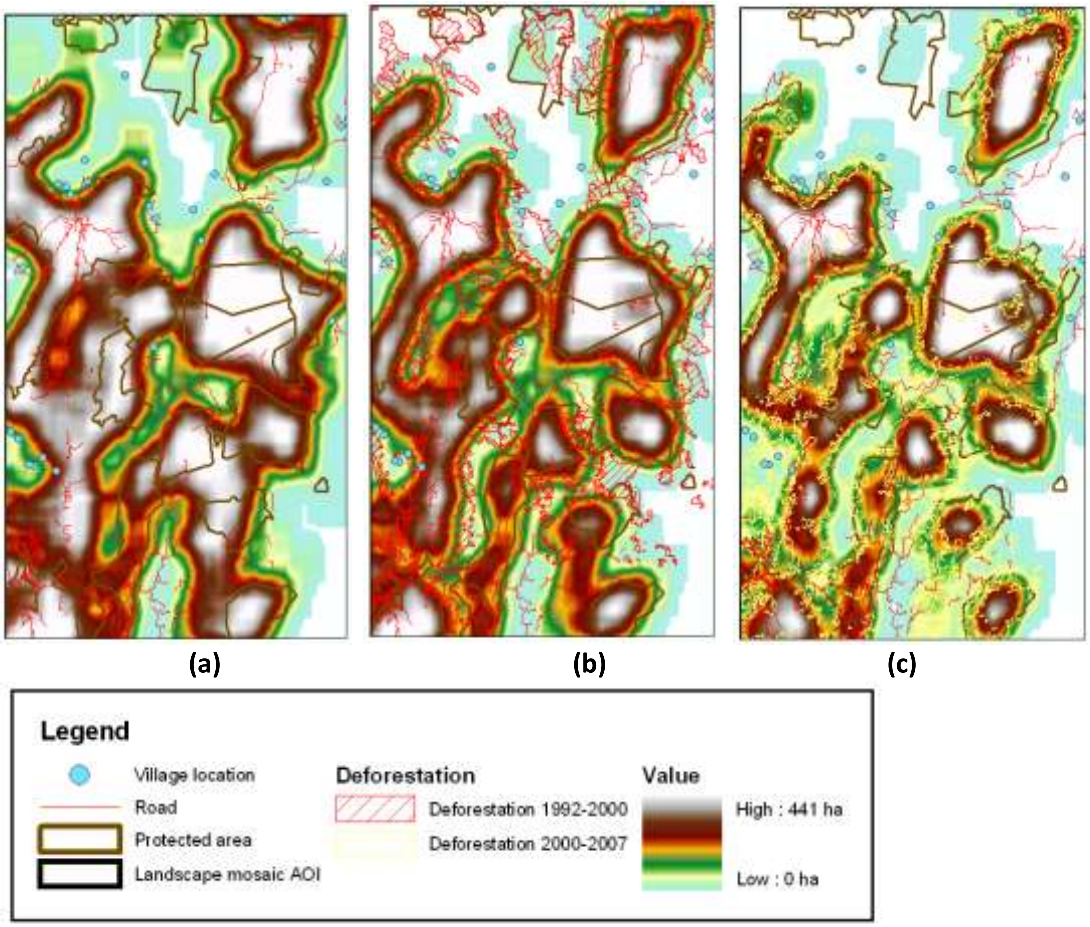

Figure 68. Time series of total core area of forest: (a) total core area in 1992; (b) total core area in 2000 with deforestation in 1992–2000; (c) total core area in 2007 with deforestation in 2000–2007

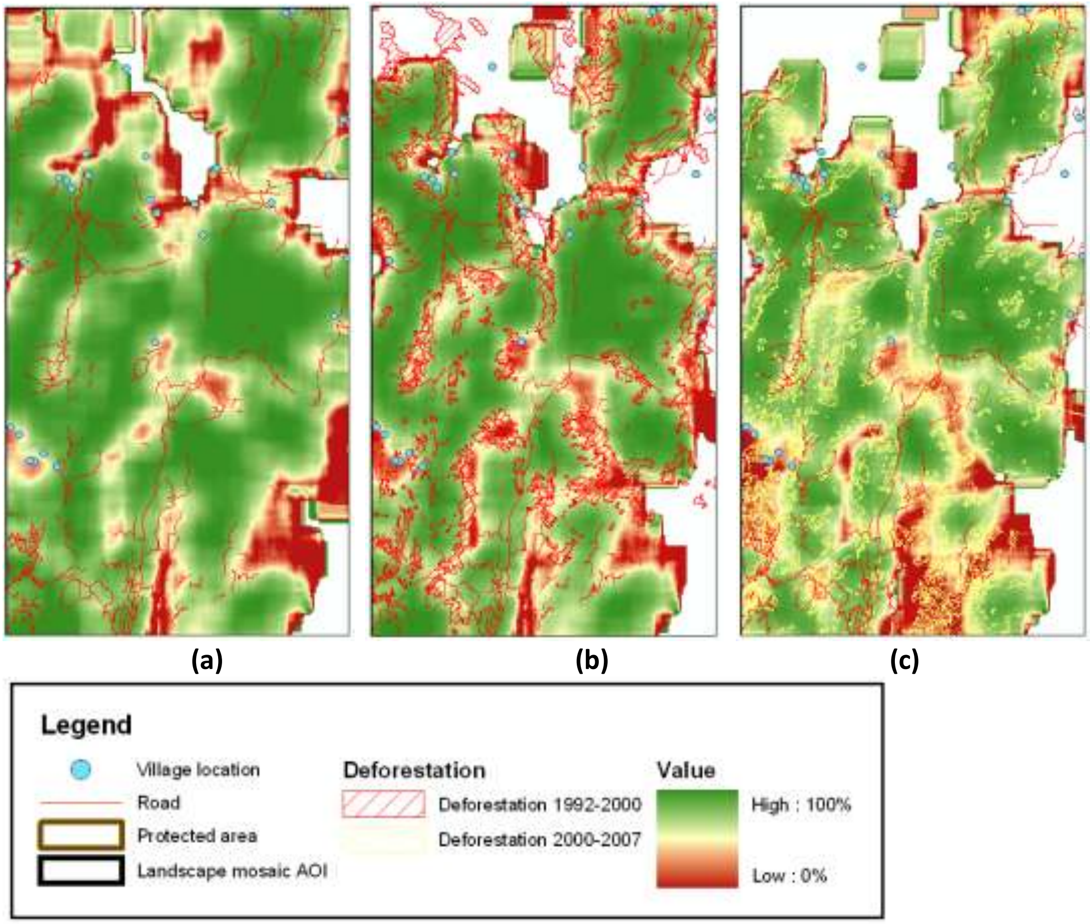

Figure 69. Time series of aggregation index of forest: (a) aggregation index in 1992; (b) aggregation index in 2000 with deforestation in 1992–2000; (c) aggregation index in 2007 with deforestation in 2000–2007

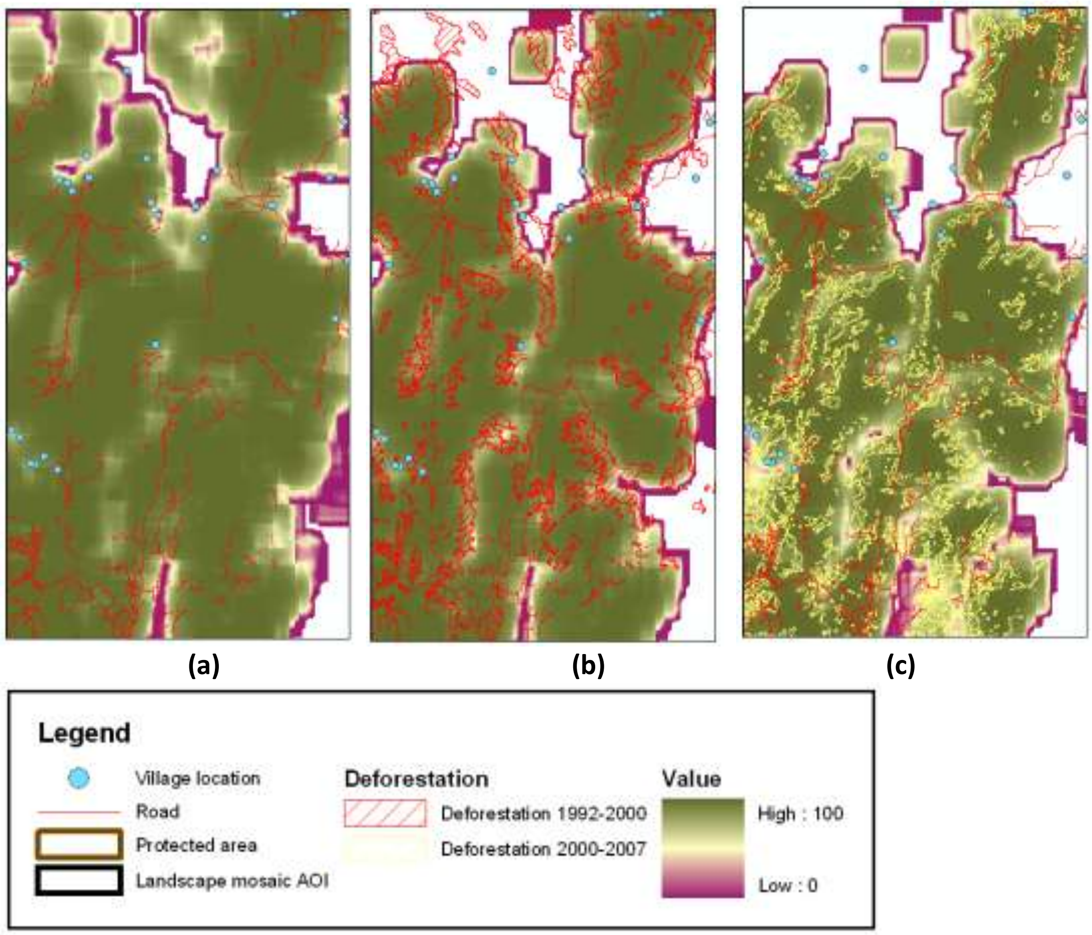

Figure 70. Time series of connectivity of forest: (a) connectivity in 1992; (b) connectivity in 2000 with deforestation in 1992–2000; (c) connectivity in 2007 with deforestation in 2000–2007

Next steps

The results of the on-going research will be further analysed and used for more detailed work, some of which is listed below.

- Linking the analysis to on-the-ground knowledge of trends, drivers and livelihoods
- Adding more data in the time series of Lao PDR (periods I and II), Cameroon and Madagascar (period II)
- Further classifying the land-use and land-cover types by differentiating forests based on density and by differentiating tree cover based on the number of dominant tree species (monoculture or mixed)
- Comparing land-use and land-cover changes inside and outside protected areas
- Groundtruthing for accuracy analysis
- Linking the analysis with the results of quick tree diversity surveys
- Using quick tree diversity surveys and analyses of dispersal to experiment with different sets of parameters to derive functional indices that reflect ecological processes and species-specific characteristics
- Exploring more indices that can quantify ecological properties of landscapes beyond visualisation
- Scenario analysis from visioning exercises to identify opportunities and constraints for biodiversity conservation in landscape mosaics and, therefore, options and possible interventions (policies, rewards for environmental services)

Conclusion

Changes in landscape composition and configuration over time owing to land-use and land-cover changes, including deforestation, are marked in the five landscapes of Bungo (Indonesia), Viengkham (Lao PDR), Manompana (Madagascar), Takamanda-Mone (Cameroon) and East Usambara (Tanzania). Except for Viengkham (with only two time series the data is very limited), other landscapes experienced decreases of forest cover over time at varying rates. Subsequent land use and land cover post-deforestation also varied from fallow, mixed-tree-based systems such as rubber and cinnamon or monoculture trees such as oil palm and acacia, cropland and settlements. Based on forest and tree-cover fractions, the order of forest transition stages, from earliest to the most advanced, in the landscapes under study is Takamanda-Mone, Viengkham, Manompana, East Usambara and Bungo, with Bungo being close to reaching the reversal mode from declining forest cover to increasing tree cover.

The spatial pattern of deforestation is determined by topography and transportation networks (roads and rivers) as well as the configuration of forest blocks and settlement locations and population densities. Changes in landscape-level indices indicate the loss of forest core area, increased fragmentation and reduced connectivity over time, and can be used as a quick criteria to assess risks of extinction of species with particular characteristics (habitat-specialised species are sensitive to rapid reduction of the forest core area; species with no ability to migrate swiftly are sensitive to a rapid increase of fragmentation; and species which do not disperse their propagules broadly enough are sensitive to a rapid decrease of connectivity). The case of East Usambara is the worst among the five landscapes for such habitat-specialised, sedentary and narrowly dispersed species because of its high rate of habitat loss simultaneous with rapid increase of fragmentation and decrease in connectivity.

Spatial variations of forest core areas, aggregation and connectivity indices across the landscapes (indices at sub-landscape level compute across the entire landscape), which can be visualised as maps, can offer valuable information and function as tools for negotiation platforms within land-use-planning processes. Past spatial patterns of deforestation can suggest where within the landscape the future deforestation will take place. In conjunction with scenario simulations based on multi-agent modelling, empirical modelling or spatially explicit driver modelling, projection of likely areas of deforestation based on past spatial deforestation patterns can spot vulnerable area of forest core area loss, fragmentation and reduced connectivity. This will help stakeholders to jointly produce guidelines, criteria and indicators of multifunctional landscapes concerning biodiversity and identify options for ‘optimal’ landscapes where opportunities lost are lowest and conservation potential is highest.

References

Akiefnawati R, Villamor GB, Zulfikar F, Budisetiawan I, Mulyoutami E, Ayat A, van Noordwijk M. 2010. *Stewardship agreement to reduce emissions from deforestation and degradation (REDD): Lubuk Beringin's hutan desa as the first village forest in Indonesia.* Working Paper 102. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Program.

Bhagwat SA, Willis KJ, Briks HJB, Whittaker RJ. 2008. Agroforestry: A refuge for tropical biodiversity? *Trends in Ecology and Evolution* 23(5): 261–267.

Collen B, Ram M, Zamin T, McRae L. 2008. The tropical biodiversity data gap: addressing disparity in global monitoring.*Tropical Conservation Science* 1 (2): 75–88.

Ekadinata A, Vincent G. 2008. Dinamika Tutupan Lahan Kabupaten Bungo, Jambi. In: Adnan H, Tadjudin D, Yuliani L, Komarudin H, Lopulalan D, Siagian Y, Munggoro D, eds. 2008. *Belajar Dari Bungo: Mengelola Sumberdaya Alam di Era Desentralisasi*. Bogor, Indonesia: Center for International Forestry Research.

Giller KE, Bignell DE, Lavelle P, Swift MJ, Barrios E, Moreira F, van Noordwijk M, Barois I, Karanja N, Huising J. 2005. Soil biodiversity in rapidly changing tropical landscapes: scaling down and scaling up. In: Usher MB, Bardgett R, Hopkins DW. *Biological Diversity and Function in Soils*. p. 295–318. Cambridge, UK: Cambridge University Press.

Ewers RM, Marsh CJ, Wearn OR. 2010. Making statistics biologically relevant in fragmented landscapes. *Trends in Ecology and Evolution* 25: 699–704.

Gardner TA, Barlow J, Chazdon R, Ewers RM, Harvey CA, Peres CA, Sodhi NS. 2009. Prospects for tropical forest biodiversity in a human-modified world. *Ecology Letters* 12: 561–582.

Lian PK, Levang P, Ghazoul J . 2009. Designer landscapes for sustainable biofuels. *Trends in Ecology and Evolution* 24: 431–438.

Krauss J, Bommarco R, Guardiola M, Heikkinen RK, Helm A, Kuussaari M, Lindborg R, Öckinger E, Pärtel M, Pino J, Po J, Raatikainen KM, Sang A, Stefanescu C, Teder T, Zobel M, Steffan-Dewenter I. 2010. Habitat fragmentation causes immediate and timedelayed biodiversity loss at different trophic levels. *Ecology Letters* 13: 597–605.

Kuussaari M, Bommarco R, Heikkinen RK, Helm A, Krauss J, Lindborg R, Öckinger E, Pärtel M, Pino J, Rodà F, Stefanescu C. 2009. Extinction debt: a challenge for biodiversity conservation. *Trends in Ecology and Evolution* 24: 564–571.

Lindenmayer D, Hobbs RJ, Montague-Drake R, Alexandra J, Benett A, Burgman M, Calhoun A, Cramer V, Cullen P, Driscoll D, Fahrig L, Fischer J, Franklin J, Haila Y, Hunter M, Gibbons P, Lake S, Luck G, MacGregor C, McIntyre S, MacNally R, Manning A, Miller J, Mooney H, Noss R, Possingham H, Saunders D, Schmiegelow F, Scott M, Simberloff D, Sisk T, Tabor G, Walker B, Woinarski J, Zavaleta E. 2008. A checklist for ecological managment of landscapes for conservation. *Ecology Letters* 11: 78–91.

Martini E, Akiefnawati R, Joshi L, Dewi S, Ekadinata A, Feintrenie R, van Noordwijk M. 2010. *Rubber agroforests and governance: at the interface between conservation and livelihoods in Bungo district, Jambi province, Indonesia*. Working Paper 10X. Bogor, Indonesia: World Agroforestry Centre Southeast Asia Regional Program.

O'Connor T. 2005. Birds in coffee agroforestry systems of West Lampung, Sumatra. Doctoral Thesis. Adelaide, Australia: University of Adelaide.

Pfund J-L et al. 2010. Local perceptions of trees and forests in increasingly globalized tropical landscapes. Manuscript in preparation.

Mather AS. 1992. The forest transition. *Area* 24(4): 367–379.

McGarigal K, Marks BJ. 1995. *FRAGSTATS: spatial pattern analysis program for quantifying landscape structure*. Portland, OR: US Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Mc Neely JA, Schroth G. 2006. Agroforestry and biodiversity conservation: traditional practices, present dynamics and lessons for the future. *Biodiversity and Conservation* 15: 549–554.

Rasnovi S. 2006. Ekologi regenerasi tumbuhan berkayu pada sistem agroforest karet. PhD Thesis. Bogor, Indonesia: Insitut Pertanian Bogor.

Sala OE, Chapin III FS, Armesto JJ, Berlow E, Bloomfield J, Dirzo R, Huber-Sanwald E, Huenneke LF, Jackson RB, Kinzig A, Leemans R, Lodge DM, Mooney HA, Oesterheld M, Poff NL, Sykes MT, Walker BH, Walker M, Wall DH. 2000. Global biodiversity scenarios for the year 2100. *Science* 287: 1770–1774.

Swallow B, Boffa J-M, Scherr SJ. 2006. The potential for agroforestry to contribute to the conservation and enhancement of landscape biodiversity. In: Garrity DP, Okono A, Grayson M, Parrott S, eds. *World Agroforestry into the future*. Nairobi: World Agroforestry Centre (ICRAF). p. 95–101.

Tilman D, May RM, Lehman CL, Nowak MA. 1994. Habitat destruction and the extinction debt. *Nature* 371: 65–66.

Tilman D, Fargione J, Wolff B, D'Antonio C, Dobson A, Howarth R, Schindler D, Schlesinger WH, Simberloff D, Swackhamer D. 2001. Forecasting agriculturally driven global environmental change. *Science* 292: 281–284.

Uezu A. 2008. Can agroforest woodlots work as stepping stones for birds in the Atlantic forest region? *Biodiversity Conservation* 17: 1907–1922.

Van Noordwijk M. 2006. *Equipping integrated natural resource managers for healthy agroforestry landscapes*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Working papers in this series

2005

1. Agroforestry in the drylands of eastern Africa: a call to action.
2. Biodiversity conservation through agroforestry: managing tree species diversity within a network of community-based, nongovernmental, governmental and research organizations in western Kenya.
3. Invasion of prosopis juliflora and local livelihoods: case study from the Lake Baringo area of Kenya.
4. Leadership for change in farmers organizations: training report: Ridar Hotel, Kampala, 29th March to 2nd April 2005.
5. Domestication des espèces agroforestières au Sahel: situation actuelle et perspectives.
6. Relevé des données de biodiversité ligneuse: manuel du projet biodiversité des parcs agroforestiers au Sahel.
7. Improved land management in the Lake Victoria Basin: TransVic Project's draft report.
8. Livelihood capital, strategies and outcomes in the Taita hills of Kenya.
9. Les espèces ligneuses et leurs usages: les préférences des paysans dans le Cercle de Ségou, au Mali.
10. La biodiversité des espèces ligneuses: Diversité arborée et unités de gestion du terroir dans le Cercle de Ségou, au Mali.

2006

11. Bird diversity and land use on the slopes of Mt Kilimanjaro and the adjacent plains, Tanzania.
12. Water, women and local social organization in the Western Kenya Highlands.
13. Highlights of ongoing research of the World Agroforestry Centre in Indonesia.
14. Prospects of adoption of tree-based systems in a rural landscape and its likely impacts on carbon stocks and farmers' welfare: The FALLOW Model Application in Muara Sungkai, Lampung, Sumatra, in a 'Clean Development Mechanism' context.
15. Equipping integrated natural resource managers for healthy agroforestry landscapes.
16. Are they competing or compensating on farm? Status of indigenous and exotic tree species in a wide range of agro-ecological zones of Eastern and Central Kenya, surrounding Mt Kenya.
17. Agro-biodiversity and CGIAR tree and forest science: approaches and examples from Sumatra.
18. Improving land management in eastern and southern Africa: a review of policies.
19. Farm and household economic study of Kecamatan Nanggung, Kabupaten Bogor, Indonesia: a socio-economic baseline study of agroforestry innovations and livelihood enhancement.
20. Lessons from eastern Africa's unsustainable charcoal business.
21. Evolution of RELMA's approaches to land management: lessons from two decades of research and development in eastern and southern Africa.
22. Participatory watershed management: Lessons from RELMA's work with farmers in eastern Africa.
23. Strengthening farmers' organizations: the experience of RELMA and ULAMP.

24. Promoting rainwater harvesting in eastern and southern Africa.

25. The role of livestock in integrated land management.

26. Status of carbon sequestration projects in Africa: potential benefits and challenges to scaling up.

27. Social and environmental trade-offs in tree species selection: a methodology for identifying niche incompatibilities in agroforestry [appears as AHI Working Paper 9].

28. Managing tradeoffs in agroforestry: from conflict to collaboration in natural resource management [appears as AHI Working Paper 10].

29. Essai d'analyse de la prise en compte des systemes agroforestiers pa les legislations forestieres au Sahel: cas du Burkina Faso, du Mali, du Niger et du Senegal.

30. Etat de la recherche agroforestière au Rwanda etude bibliographique, période 1987–2003.

2007

31. Science and technological innovations for improving soil fertility and management in Africa: a report for NEPAD’s Science and Technology Forum.

32. Compensation and rewards for environmental services.

33. Latin American regional workshop report compensation for ecosystem services.

34 Asia regional workshop on compensation for ecosystem services.

35 African regional workshop on compensation for ecosystem services.

36 Exploring the inter-linkages among and between compensation and rewards for ecosystem services (CRES) and human well-being.

37 Criteria and indicators for environmental service compensation and reward mechanisms: realistic, voluntary, conditional and pro-poor.

38 The conditions for effective mechanisms of compensation and rewards for environmental services.

39 Organization and governance for fostering pro-poor compensation for environmental services.

40 How important are different types of compensation and reward mechanisms shaping poverty and ecosystem services across Africa, Asia and Latin America over the next two decades?

41. Risk mitigation in contract farming: the case of poultry, cotton, woodfuel and cereals in East Africa.

42. The RELMA savings and credit experiences: sowing the seed of sustainability

43. Policy and institutional context for NRM in Kenya: challenges and opportunities for Landcare.

44. Nina-Nina Adoung Nasional di So! Field test of rapid land tenure assessment (RATA) in the Batang Toru watershed, North Sumatra.

45. Is Hutan Tanaman Rakyat a new paradigm in community-based tree planting in Indonesia?

46. Socio-economic aspects of brackish water aquaculture (tambak) production in Nanggroe Aceh Darrusalam.

47. Farmer livelihoods in the humid forest and moist savannah zones of Cameroon.

48. Domestication, genre et vulnérabilité:pParticipation des femmes, des jeunes et des catégories les plus pauvres à la domestication des arbres agroforestiers au Cameroun.

49. Land tenure and management in the districts around Mt Elgon: an assessment presented to the Mt Elgon ecosystem conservation programme.

50. The production and marketing of leaf meal from fodder shrubs in Tanga, Tanzania: a pro-poor enterprise for improving livestock productivity.

51. Buyers perspectives on environmental services (ES) and commoditization as an approach to liberate ES markets in the Philippines.

52. Towards community-driven conservation in southwest China: reconciling state and local perceptions.

53. Biofuels in China: an analysis of the opportunities and challenges of Jatropha curcas in Southwest China.

54. Jatropha curcas biodiesel production in Kenya: economics and potential value chain development for smallholder farmers

55. Livelihoods and forest resources in Aceh and Nias for a sustainable forest resource management and economic progress.

56. Agroforestry on the interface of orangutan conservation and sustainable livelihoods in Batang Toru, North Sumatra.

2008

57. Assessing hydrological situation of Kapuas Hulu Basin, Kapuas Hulu Regency, West Kalimantan.

58. Assessing the hydrological situation of Talau Watershed, Belu Regency, East Nusa Tenggara.

59. Kajian kondisi hidrologis DAS Talau, Kabupaten Belu, Nusa Tenggara Timur.

60. Kajian kondisi hidrologis DAS Kapuas Hulu, Kabupaten Kapuas Hulu, Kalimantan Barat.

61. Lessons learned from community capacity-building activities to support agroforest as sustainable economic alternatives in Batang Toru orangutan habitat conservation program.

62. Mainstreaming climate change in the Philippines.

63. A conjoint analysis of farmer preferences for community forestry contracts in the Sumber Jaya Watershed, Indonesia.

64. The Highlands: a shower water tower in a changing climate and changing Asia.

65. Eco-certification: can it deliver conservation and development in the tropics?

66. Designing ecological and biodiversity sampling strategies: towards mainstreaming climate change in grassland management.

67. Participatory poverty and livelihood assessment report, Kalahan, Nueva Vizcaya, the Philippines.

68. An assessment of the potential for carbon finance in rangelands.

69. ECA trade-offs among ecosystem services in the Lake Victoria Basin.

70. Le business plan d’une petite entreprise rurale de production et de commercialisation des plants des arbres locaux: cas de quatre pépinières rurales au Cameroun.

71. Les unités de transformation des produits forestiers non ligneux alimentaires au Cameroun: diagnostic technique et stratégie de développement Honoré Tabuna et Ingratia Kayitavu.

72. Les exportateurs camerounais de safou (Dacryodes edulis) sur le marché sous régional et international: profil, fonctionnement et stratégies de développement.

73. Impact of the Southeast Asian Network for Agroforestry Education (SEANAFE) on agroforestry education capacity.

74. Setting landscape conservation targets and promoting them through compatible land use in the Philippines.

75. Review of methods for researching multistrata systems.

76. Study on economical viability of Jatropha curcas L. plantations in Northern Tanzania: assessing farmers' prospects via cost-benefit analysis.

77. Cooperation in agroforestry between Ministry of Forestry of Indonesia and International Centre for Research in Agroforestry.

78. China's bioenergy future: an analysis through the lens of Yunnan province.

79. Land tenure and agricultural productivity in Africa: a comparative analysis of the economics literature and recent policy strategies and reforms.

80. Boundary organizations, objects and agents: linking knowledge with action in agroforestry watersheds.

81. Reducing emissions from deforestation and forest degradation (REDD) in Indonesia: options and challenges for fair and efficient payment distribution mechanisms.

2009

82. Mainstreaming climate change into agricultural education: challenges and perspectives.

83. Challenging conventional mindsets and disconnects in conservation: the emerging role of eco-agriculture in Kenya's landscape mosaics.

84. Lesson learned RATA garut dan bengkunat: suatu upaya membedah kebijakan pelepasan kawasan hutan dan redistribusi tanah bekas kawasan hutan.

85. The emergence of forest land redistribution in Indonesia.

86. Commercial opportunities for fruit in Malawi.

87. Status of fruit production processing and marketing in Malawi.

88. Fraud in tree science.

89. Trees on farms: analysis of global extent and geographical patterns of agroforestry.

90. The springs of Nyando: water, social organization and livelihoods in Western Kenya.

91. Building capacity toward region-wide curriculum and teaching materials development in agroforestry education in Southeast Asia.

92. Overview of biomass energy technology in rural Yunnan.

93. A pro-growth pathway for reducing net GHG emissions in China.

94. Analysis of local livelihoods from past to present in the central Kalimantan Ex-Mega Rice Project area.

95. Constraints and options to enhancing production of high quality feeds in dairy production in Kenya, Uganda and Rwanda.

96. Agroforestry education in the Philippines: status report from the Southeast Asian Network for Agroforestry Education (Agroforestry education in the Philippines: status report from the Southeast Asian Network for Agroforestry Education (SEANAFE).

2010

97. Economic viability of Jatropha curcas L. plantations in Northern Tanzania: assessing farmers' prospects via cost-benefit analysis.

98. Hot spot of emission and confusion: land tenure insecurity, contested policies and competing claims in the central Kalimantan Ex-Mega Rice Project area.

99. Agroforestry competences and human resources needs in the Philippines.

100. CES/COS/CIS paradigms for compensation and rewards to enhance environmental services.

101. Case study approach to region-wide curriculum and teaching materials development in agroforestry education in Southeast Asia.

102. Stewardship agreement to reduce emissions from deforestation and degradation (REDD): Lubuk Beringin's Hutan Desa as the first village forest in Indonesia.

103. Landscape dynamics over time and space from an ecological perspective.

104. A performance-based reward for environmental services: an action research case of "RiverCare" in Way Besai sub-watersheds, Lampung, Indonesia.

105. Smallholder voluntary carbon scheme: an experience from Nagari Paningahan, West Sumatra, Indonesia.

106. Rapid Carbon Stock Appraisal (RACSA) in Kalahan, Nueva Vizcaya, Philippines.

107. Tree domestication by ICRAF and partners in the Peruvian Amazon: lessons learned and future prospects in the domain of the Amazon Initiative eco-regional program.

108. Memorias del Taller Nacional: "Iniciativas para reducir la deforestación en la region Andino Amazónica", 9 de Abril del 2010. Proyecto REALU Peru.

109. Percepciones sobre la equidad y eficiencia en la cadena de valor de REDD en Perú: Reporte de Talleres en Ucayali, San Martín y Loreto, 2009. Proyecto REALU Perú.

110. Reducción de emisiones de todos los Usos del Suelo: reporte del Proyecto REALU Perú Fase 1.

111. Programa Alternativas a la Tumba-y-Quema (ASB) en el Perú: Informe Resumen y Síntesis de la Fase II. 2da. versión revisada.

112. Estudio de las cadenas de abastecimiento de germoplasma forestal en la amazonía Boliviana.

113. Biodiesel in the Amazon.

114. Estudio de mercado de semillas forestales en la amazonía Colombiana.

115. Estudio de las cadenas de abastecimiento de germoplasma forestal en Ecuador.

The World Agroforestry Centre is an autonomous, non-profit research organization whose vision is a rural transformation in the developing world where smallholder households strategically increase their use of trees in agricultural landscapes to improve their food security, nutrition, income, health, shelter, energy resources and environmental sustainability. The Centre generates science-base knowledge about the diverse role that trees play in agricultural landscapes, and uses its research to advance policies and practices that benefit the poor and the environment.

United Nations Avenue, Gigiri - PO Box 30677 - 00100 Nairobi, Kenya
Tel: +254 20 7224000 or via USA +1 650 833 6645
Fax: +254 20 7224001 or via USA +1 650 8336646
Southeast Asia Regional Program - Sindang Barang, Bogor 16115
PO Box 161 Bogor 16001, Indonesia
Tel: +62 251 8625 415 - Fax: +62 251 8625 416
www.worldagroforestry.org