

IMPACT OF FORESTLAND TENURE CHANGES ON FOREST COVER, STOCKING AND TREE SPECIES DIVERSITY IN AMANI NATURE RESERVE, TANZANIA

MATHEW M. MPANDA^{1*}, EMMANUEL J. LUOGA², GEORGE C. KAJEMBE², TRON EID³

¹*World Agroforestry Centre (ICRAF), P. O. Box 6226, Dar es Salaam, Tanzania*

²*Sokoine University of Agriculture, P. O. Box 3000, Morogoro, Tanzania*

³*Norwegian University of Life Sciences, P. O. Box 5003, NO-1432 Aas, Norway*

ABSTRACT

The aim of the present study was to evaluate the impact of changes from private to state tenure on forest resources for three blocks in Amani Nature Reserve. The resource changes were determined in terms of forest cover, forest stocking and tree species diversity over a period of six to eight years. When considering the three blocks as one entity one may in general maintain that there have been positive changes regarding forest cover. There were differences between the blocks, however. The proportions of dense and semi-closed forest increased by around 14% in the former tea company block, remained unchanged in the former farmland and decreased by around 12% in the former sisal company block. The changes in stocking parameters and tree species diversity were mainly positive, but none were statistically significant. Although the results were somewhat ambiguous evidence of positive impacts as a result of the tenure changes was identified. This is in line with the main aim of establishing nature reserves focusing on conservation values. More research, however, is required regarding impacts of tenure changes on livelihood for those living adjacent to the nature reserve.

Key words: deforestation, biodiversity conservation, private and state tenure, East Usambara Mountains

INTRODUCTION

Tanzania has a total area of 945,000 km², of which 353 000 km² (37%) is covered by forests and woodlands that play multiple roles for the majority of people, ranging from household subsistence to commercial scale (URT 2009). It is one of the richest and most diverse countries in Africa in terms of both species and habitats (IUCN 1990). The forest and woodlands comprise different vegetation types and serve for mitigation of and adaptation to climate change, for biodiversity conservation, watershed services, fuelwood and other services (URT 2003, 2009). The role of these forests has, however, been undermined by deforestation which is estimated at 412,000 ha per annum. Causes of deforestation are mainly human disturbances including encroachment, wildfire, illegal mining, pit-sawing, illegal harvesting for building materials and excessive collection of fuel wood and herbal medicines. Deforestation has been magnified

*Correspondence: m.mpanda@cgiar.org or mshauri2005@yahoo.com; fax: +255 222700660

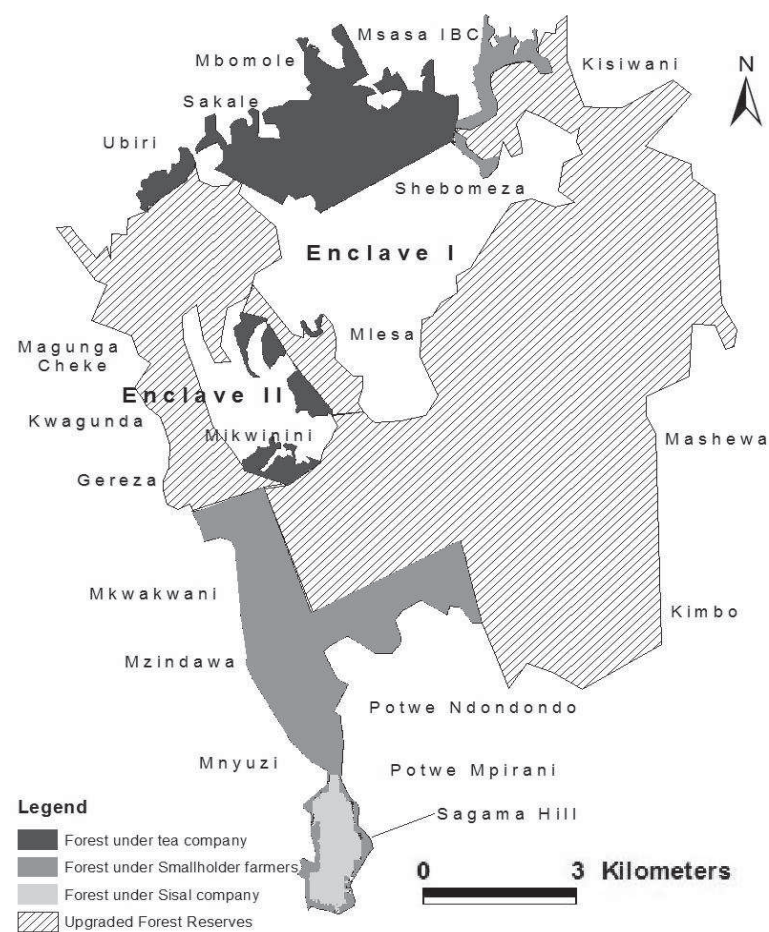
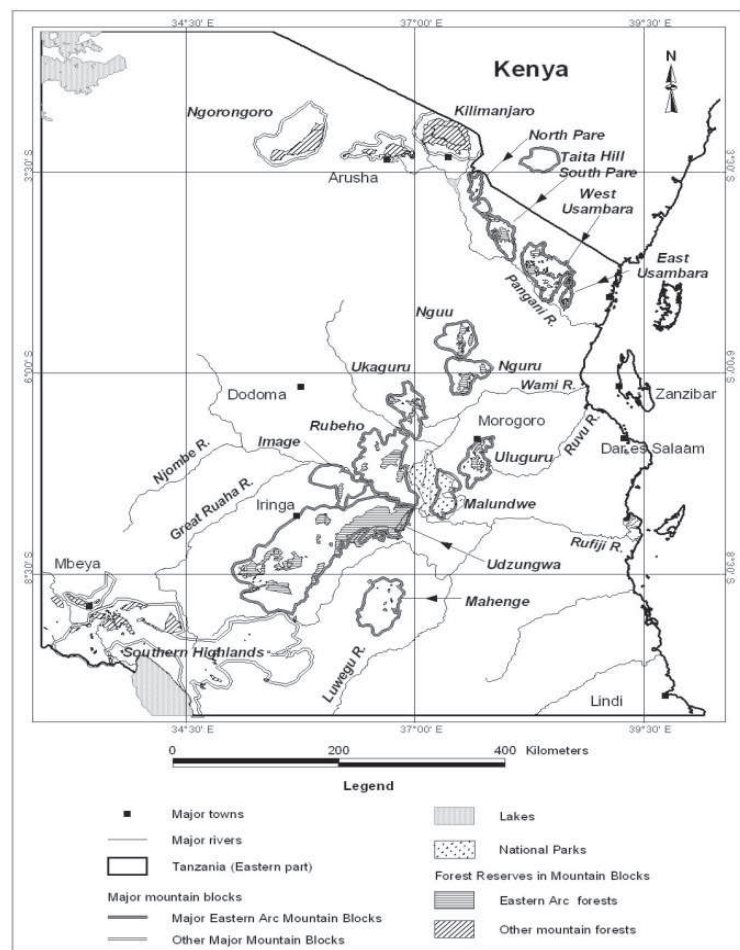


Figure 1: Map showing the boundary of ANR and the respective previous tenure regimes

by limited human and financial resources to implement proper management of forests in the country (URT 2009).

In the 1990s Tanzania undertook policy reforms in the natural resources sector and embraced the new paradigm of decentralization (e.g. Kajembe *et al.* 2008, Zahabu *et al.* 2009). The reforms promoted participation of local communities living adjacent to forests in management and utilization, and involved introduction of joint forest management (JFM) and community-based forest management (CBFM) (URT 1998). Furthermore, the country embarked on elevating the status of forest reserves with high biodiversity and strategic importance into nature reserves using the International Union for Conservation of Nature (IUCN) categories of protected areas (URT 1998, IUCN 2010). The IUCN (2010), has six categories with strict nature reserve topping the list and aims at protecting biodiversity and possibly geological/geomorphical features, where human visitation, use and impacts are strictly controlled and limited to ensure protection of the conservation values. In the Tanzanian context, the nature reserves have more legal protection and financial autonomy than other forest reserves enabling them to address most of the management constraints (ANR 2007).

Amani Nature Reserve (ANR) was established in 1997 in the East Usambara Mountains by merging six state owned forest reserves and by annexation of private forests (EUCAMP 2002, ANR 2007). The private forests (Figure 1) were owned by a tea company (located mostly in the northern part of the reserve), various smallholder farmers (mostly in the southern part of the reserve, with a small part in the north-east) and a sisal company (forming a peninsula at the extreme south of the reserve). The western part of the ANR is characterized by a steep escarpment which runs southward forming a ridge at the far south-end known as Sagama hill (previously owned by the sisal company). This landform influenced adjacent villages to locate in the lowland, though cultivation near ANR border is conducted. This was a result of international and local conservation efforts to restore this important biodiversity site (AFIMP 1988, EUCAMP 2002), including relief to the challenges associated to its fragmentation (Newmark 1998). Bilateral and multi-lateral development partners invested more than \$ 15 million in establishing ANR, protecting critical catchment forests, and rehabilitating the commercial tea estates on the East Usambara Mountains (Newmark 2004). The annexation of private forests by the ANR re-defined tenure arrangements from private to state regime (EUCAMP 2002), and this added complexity and debate to the decentralization process of forest management in the country (Kajembe *et al.* 2008, Vihemaki 2009).

The annexed private forest blocks had different land use history and property rights. The forest blocks owned by the tea and the sisal companies were leased lands with clear property rights, while the forest under smallholder farmers was mainly held customarily or under freehold. The forests under the tea and sisal companies had sustained encroachment and illegal timber and fuelwood extraction (C. T. Sawe, pers. comm.). The smallholder farmer's forest patches (658 farmers involved) were cultivated with shade tolerant species such as

Cardamom (*Elettaria cardamomum* (L.) Maton. and banana (*Musa* sp.) for part of them and stayed as remnants of undisturbed forests for the others. Under the new state tenure regime all these forest blocks received a common management approach (ANR 2007).

The aim of the present study was to evaluate the impact of tenure changes on the forest resources. The forest resources were assessed in terms of forest cover, forest stocking and tree species diversity before and after the tenure changes.

MATERIAL AND METHODS

Study site

ANR lies between 5°05'–5°14'S and 38°40'–38°32'E in the north-eastern part of Tanzania in Tanga Region (Figure 1), and covers 8,380 ha (Mathew *et al.* 2009). The reserve forms the southern and largest forested mountain block of the East Usambara Mountains. The East Usambara Mountains are recognised as an important conservation priority site due to high numbers of endemic, near-endemic and threatened tree and vertebrate species (Burgess *et al.* 2007, Gereau *et al.* 2010). ANR receives a mean annual rainfall of 1,918 mm with up to 2,262 mm in some places. The mean annual temperature at about 900 m altitude is 20.6°C with a mean daily maximum temperature of 24.9°C and a mean daily minimum temperature of 16.3°C (Hamilton 1989). Altitude in the ANR ranges between 300 and 1,130 m.a.s.l. (ANR 2007). The population in the 19 villages adjacent to ANR is 27,899 of which about 15% live in two enclaves (see Figure 1). Crop farming is the main economic activity with average farm size ranging from 2.7 ha to 3.5 ha (ANR 2007).

Data collection

Forest cover assessment

Forest cover assessment was done using remote sensing and GIS techniques. Landsat TM satellite images of 2000 and 2006 were used. The 2000 image (taken on 22 January 2000) was used to assess forest cover at the end of the private tenure regime. The 2006 image (taken on 23 February 2006) was used to depict the situation after six years of state tenure regime. The timing of image capture was in dry season to ensure minimal cloud cover. Hand-held GPS (Garmin 76x) was used to record waypoints of different places having various vegetation types for serving as training sites during image analysis.

Forest inventory

In 1999/2000, a number of permanent sample plots (PSPs) were established in ANR. The reserve was first divided into a rectangular 450×900 m grid. Then 50×20 m PSPs, altogether 180, were systematically laid in the south-east corner of each rectangle (Frontier Tanzania 2001). In 2008 a repetitive survey was carried out on 28 PSPs belonging to the blocks that previously were under private tenure. All trees ≥ 10 cm DBH (Diameter at Breast Height) were re-measured (DBH), and re-identified by means of a botanist assisted by local people. In addition, 31 trees of various sizes, belonging to 23 species, were randomly sampled within the sample plots and measured (DBH and height) for establishing equations used to estimate the height of unmeasured trees.

Data analyses

Forest cover analysis

ERDAS Imagine, ArcView GIS 3.2 and ArcGIS Desktop 10 software were used in image data pre-processing and analysis. Image sub-setting was conducted to the images of 2000 and 2006 to obtain areas of interest, i.e. blocks formerly owned by the tea company, smallholder farmers and the sisal company. The exact boundaries between the different blocks and between the blocks and remaining forest areas were in some cases not clear or available from old maps. In such cases the boundaries settled for the analyses were based on information given by a few key informants who were familiar with the situation before the establishment of the ANR.

Forest cover maps for 2000 and 2006 were developed containing the following five classes: dense forest, semi-closed forest, open forest/woodland, bush/grassland and open areas. Then post classification change detection was performed in which classified forest cover maps of 2000 and 2006 were compared. The areas extracted from classification results were used assuming linear relationship to make direct computation of percentage total and annual change as shown in the following expressions used by Mbilinyi *et al.* (2006);

- i) Total change (%) = $((Area_{year\ x} - Area_{year\ x + t}) / (Area_{year\ x})) \times 100\%$;
- ii) Annual change (%) = $(Area_{year\ x} - Area_{year\ x + t}) / (Area_{year\ x} \times t_{years}) \times 100\%$,

where $Area_{year\ x}$ = area of cover at the first date (2000); $Area_{year\ x + t}$ = area of cover at the second date (2006); and, t_{years} = period in years between the first and second scene acquisition dates.

Forest stocking and tree diversity analyses

Identical procedures for estimating forest stocking and tree diversity were applied for the year 1999/2000 and 2008 data. Number of trees per plot was summarized and transformed into per hectare values (N). Basal areas for individual trees (g) were calculated according to DBH, summarised and transformed into per hectare values for the plot (G). A height-DBH relationship was developed based on the 31 sample trees to estimate individual tree height;

$$\text{iii) } \ln(\text{Ht}) = 0.638 + 0.767\ln(\text{DBH}), (R^2 = 0.79, \text{SE} = 0.11),$$

where $\ln$ = natural logarithm, Ht = height (m), DBH = diameter at breast height (cm), R = coefficient of determination, SE = standard error. For trees outside the data range of the 31 sample trees (DBH larger than 66 cm), it was assumed that height never could get larger than 52 meters (the maximum among the sample trees). For the trees measured in 2008 approximately 6% of all trees were larger than 66 cm in DBH.

The volume of individual trees was calculated according to the following equation;

$$\text{iv) } v = g * \text{Ht} * f,$$

where v = tree volume, g = tree basal area, Ht = estimated tree height and f = form factor with value 0.5. A form factor of 0.5 has traditionally been used for montane forests in Tanzania (Chamshama *et al.* 2004, Luoga *et al.* 2005). Finally, the volume of individual trees was summarized within plots and transformed into per hectare values (V).

Shannon-Wiener index (e.g. Krebs 1999) was computed within each block and compared between the 1999/2000 and 2008 data using the following expression;

$$\text{v) } H' = -\sum p_i (\ln p_i),$$

where H' = Shannon-Wiener value; p_i = proportion of the i^{th} species, $\ln$ = natural logarithm.

The statistical significance of temporal changes for stocking parameters and Shannon-Wiener index were analysed using two-tailed t-tests.

RESULTS

Results of forest cover (Fig. 2, Table 1) analyses show positive changes for dense and semi-closed forest in the block previously owned by the tea company. For the block previously under smallholder farmers the area with dense forest has decreased while the area of semi-closed forest has increased. For the block previously owned by the sisal company the area of both dense and semi-closed forests has decreased.

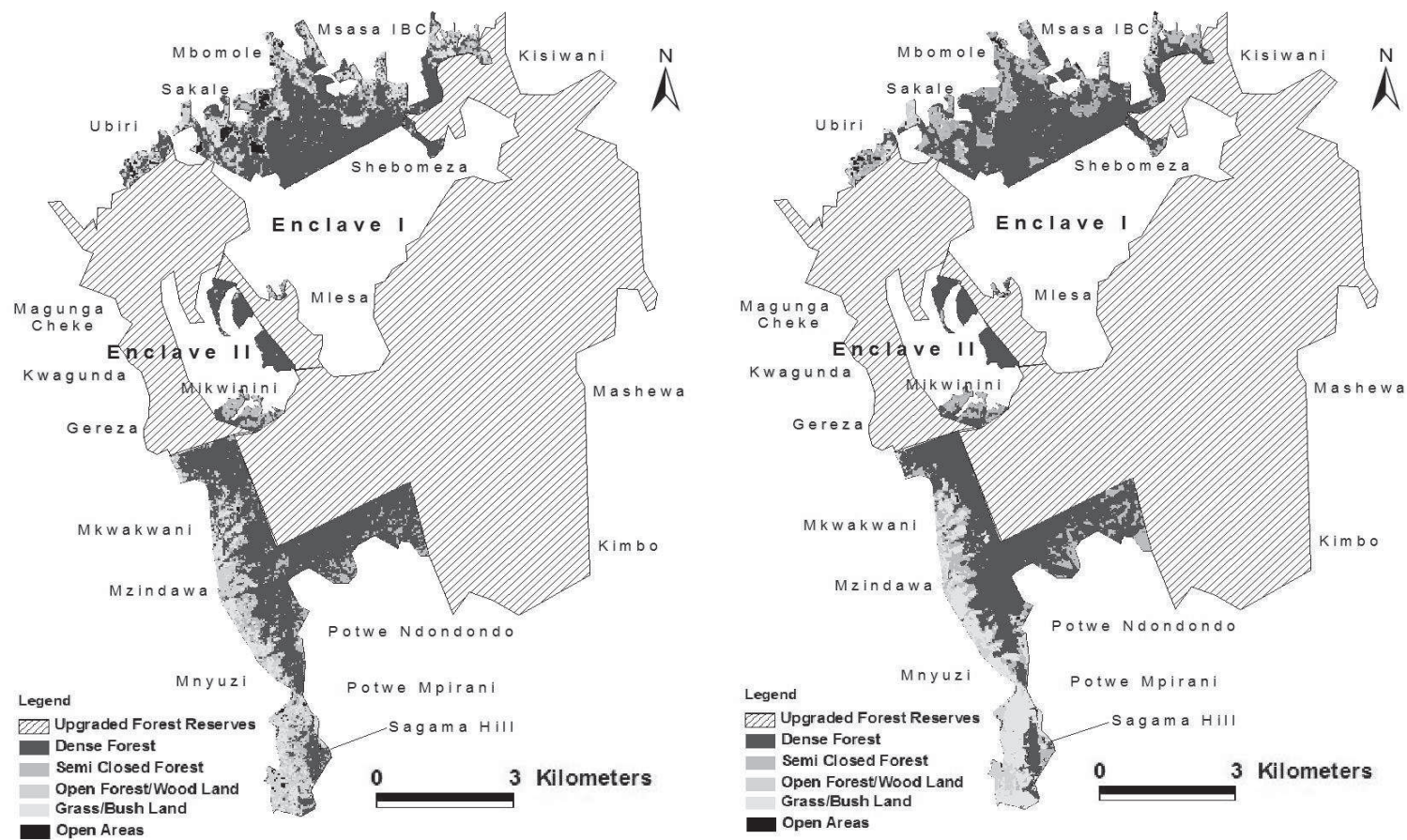


Figure 2. Forestland cover maps showing the various cover types in 2000 (left) and 2006 (right)

TABLE 1

Forest cover changes in private and state tenures in Amani Nature Reserve.

Forest block	Description	Private tenure (2000)		State tenure (2006)		Total change (ha)	Total change (%)	Annual change (%)
		Area (ha)	(%)	Area (ha)	(%)	(ha)	(%)	(%)
Tea company	Dense forest	697	71.8	729	75.1	+32	+5	+0.8
	Semi-closed forest	72	7.4	182	18.7	+110	+153	+25.5
	Open Forest/Woodland	48	4.9	17	1.8	-31	-65	-10.8
	Bushland/Grassland	119	12.3	31	3.2	-88	-74	-12.3
	Open area	35	3.6	12	1.2	-23	-66	-11.0
	All	971	100.0	971	100.0	—	—	—
Farmland	Dense forest	769	69.2	714	64.2	-55	-7	-1.2
	Semi-closed forest	133	12.0	183	16.5	+50	+38	+6.3
	Open Forest/Woodland	45	4.0	39	3.5	-6	-13	-2.2
	Bushland/Grassland	161	14.5	173	15.6	+12	+7	+1.2
	Open area	4	0.4	3	0.3	-1	-25	-4.2
	All	1112	100.0	1112	100.0	—	—	—
Sisal company	Dense Forest	46	26.6	33	19.1	-13	-28	-4.7
	Semi-closed Forest	21	12.1	12	6.9	-9	-43	-7.1
	Open Forest/Woodland	26	15.0	21	12.1	-5	-19	-3.2
	Bushland/Grassland	76	43.9	106	61.3	+30	+39	+6.6
	Open area	4	2.3	1	0.6	-3	-75	-12.5
	All	173	100.0	173	100.0	—	—	—

TABLE 2
Mean, standard error (SE) and changes for stocking parameters in private and state tenures in Amani Nature Reserve

Forest block	Parameters	Private tenure (1999/2000)		State tenure (2008)		Change (% in brackets)	P-value
		Mean	SE	Mean	SE		
Tea company ($n = 18$)	N (no.ha ⁻¹)	435	37	424	33	-11	(-2.5) 0.4027
	G (m ² h ⁻¹)	46.0	54	46.8	5.2	0.8	(1.7) 0.6369
	V (m ³ ha ⁻¹)	946.5	133.2	965.3	131.2	18.8	(2.0) 0.6826
Farmland ($n = 7$)	N (no.ha ⁻¹)	290	32	310	35	20	(6.9) 0.1453
	G (m ² h ⁻¹)	28.7	4.9	32.8	4.8	4.1	(14.3) 0.3762
	V (m ³ ha ⁻¹)	563.1	113.9	651.4	103.6	88.3	(15.7) 0.4696
Sisal company ($n = 3$)	N (no.ha ⁻¹)	137	64	163	55	26	(19.0) 0.2697
	G (m ² h ⁻¹)	11.5	5.9	13.2	6.5	1.7	(14.8) 0.0996
	V (m ³ ha ⁻¹)	209.9	119.9	239.8	132.7	29.9	(14.2) 0.1476

TABLE 3

Shannon-Wiener index changes in private and state tenures in Amani Nature Reserve.

Forest block	Private tenure (1999/2000)	State tenure (2008)	Change	P-value
Tea company (<i>n</i> = 18)	3.50	3.49	−0.01	0.3943
Farmland (<i>n</i> = 7)	3.36	3.39	+0.03	0.4650
Sisal company (<i>n</i> = 3)	2.97	3.07	+0.10	0.2654

Results of the stocking levels and changes between 1999/2000 and 2008 are shown in Table 2. An increase in number of stems, basal area and volume per hectare appeared in all blocks except for number of stems per hectare in the block formerly owned by the tea company. The changes however, were not statistically significant at 5% level.

Number of species recorded in 1999/2000 and 2008 (in brackets) were 67 (76), 45 (49) and 24 (27) for the three forest blocks previously owned by the tea company, smallholder farmers and the sisal company, respectively. Shannon-Wiener diversity indices in 1999/2000 and 2008 were not significantly different (Table 3).

DISCUSSION

A general decline of forest cover in the East Usambara Mountains has been reported by Hall *et al.* (2009) for the period 1955 to 2000. Various large scale crop plantations for coffee, tea and rubber plus timber extraction were conducted in the highlands, while lowland forests were cleared for sisal and crop farming (AFIMP 1988, Woodcock 1995, Hall *et al.* 2009). These activities attracted a lot of migrants to serve in the plantations and consequently settling in the nearby villages, which in turn opened up more forest patches to crop farming (Woodcock 1995, Hall *et al.* 2009).

As a result of all these activities, the conditions regarding the forest resources were quite different for the three blocks when ANR was established (1999/2000). In general the proportions of dense and semi-closed forest (Table 1) were higher in the former tea company and farmland blocks (79.2% and 81.2%, respectively) compared to the former sisal company block (38.7%). The conditions regarding forest stocking, i.e. number of trees, basal area and volume/ha (Table 2), and species diversity (Table 3) were also better in the former tea company and farmland blocks compared to the sisal company block.

The results for changes in forest conditions from the establishment of ANR until 2006/2008 are somewhat ambiguous. When considering the three blocks as one entity one may in general maintain that there have been positive changes regarding forest cover as well as forest stocking and tree species diversity since the tenure changes took place. There are, however, some exceptions and modifications, especially regarding differences between the blocks that need to

be discussed. The most obvious differences can be seen in forest cover changes where the proportions of dense and semi-closed forest increased by around 14% in the tea company block, remained unchanged in the former farmland and decreased by around 12% in the former sisal company block (Table 1). In general the stocking parameter changes in all blocks were positive, although not statistically significant (Table 2). Tree species diversity remained almost unchanged for all three blocks (Table 3).

The results from the sisal company block, where the proportions of dense and semi-dense forest decreased, while the stocking parameter values in general increased, are not consistent. Since the sisal company block is very small in size compared to the other blocks it is quite likely that this inconsistency is an artefact linked to the low number of sample plots. The relative standard error (i.e. standard error in percent of mean) for example regarding volume was ca. 55% for the sisal company block (3 plots), while it was ca. 14% in the tea company block, (18 plots). Another possible explanation could be that the permanent sample plots somehow benefit from a special “protection status” from the local people. Although such side effect cannot totally be ruled out, no evidence was seen during field work or given by the key informants to support this, neither for the sisal company block nor for the rest of the nature reserve.

The differences in results between the blocks may also be explained by differences in local factors such as human activities (e.g. state interventions, accessibility and adjacency to villages and forest fires) and natural conditions (e.g. terrain, elevation, vegetation).

Since the establishment of ANR, several state interventions affecting the management have taken place; i) strengthened law enforcement under state regime, ii) scaling up harvesting of *Terminalia superba* and *Tectona grandis* from the nearby state owned Longuza Forest Plantation, and iii) encouraged harvesting of *Eucalyptus* spp. woodlots in adjacent villages. The combined effect of these interventions (especially the second and third item) may have reduced pressure for wood products that previously was applied to the forests under the private regime. However, most of these alternative resources are located in the highlands and eastern part of ANR (see Figure 1), where the former tea company was located. Most of the farmland block and the entire sisal company block have probably benefited less from these initiatives, and illegal exploitation of the forest resources inside ANR has continued to some extent.

Uncontrolled forest fires have been cited as one of the direct threats to the forests of the Eastern Arc Mountain forests (FBD 2009). Active state intervention aiming for suppression of forest fires in adjacent villages of ANR has taken place. However, the shape and location of the former sisal company block as a peninsula in the south (see Figure 1) makes this block especially exposed to adjacent villages. In this part of the reserve, the forest has been highly affected by wildfires originating from neighbouring farms.

Climatically, the highlands in the northern and eastern parts of ANR are characterized by moist and humid conditions whereas the lowland areas in the

western and southern parts are mostly dry and windy. Such conditions may to some extent have influenced the results. It was, for example, observed a relatively high recruitment of canopy trees species (e.g. *Newtonia buchananii*, *Cephalosphaera usambarensis*, *Maesopsis eminii* and *Drypetes gerardii*) in the highlands. Colonization of forest gaps by some locally invasive species such as *Maesopsis eminii* spread by hornbills (*Bucerotidae*) was also observed in the highlands. On the other hand, the undergrowth in most of the southern part of ANR is composed of grasses (e.g. *Panicum* sp. and *Stipa latifolia*), which make regeneration of trees very difficult because the grasses suppress the trees and leave the ground partially bare during the dry season.

Reyes *et al.* (2006) noted that in recent years there has been a growing trend of shifting from cultivation in forests towards home gardens in the East Usambara Mountains. The scaling up of income generating activities such as butterfly farming, dairy cattle, spice cultivation, fish farming, beekeeping, vegetable gardening and ecotourism have also played a vital role in intensifying on-farm productivity. All these activities in general lessen the pressure to the forests. Whether these trends have influenced differently among the blocks, however, is not possible to verify.

On average the stocking levels (no. of trees, basal area and volume per hectare, Table 2) found in the present study were similar to observations made for other studies in the East Usambara Mountains (AFIMP 1988, Uhuru 2008). In general the results show that changes in stocking levels and diversity indices have been positive since the establishment of ANR. None of the changes were statistically significant, however. This result is similar to observations done by Blomley *et al.* (2008) on other forest blocks in the Eastern Arc Mountains. In general, the relatively short period of time (i.e. 8 years) for studying changes in this type of tropical forest accounts for small changes.

Species diversity indices (Table 3) found in the present study was similar to observations made by other studies in the East Usambara Mountains (Munishi *et al.* 2004, Uhuru 2008). Disregarding the statistical insignificance, the signs of positive changes regarding tree species diversity in the former farmland and sisal estate blocks may be attributed to land use history before the establishment of ANR. The farmland and sisal estate blocks were more disturbed as compared to the tea estate before the establishment. These disturbances might have created gaps that favoured growth of edge and pioneer species, which in turn increased local plant diversity as explained by intermediate disturbance hypothesis (Hughes *et al.* 2007, Torras and Saura 2008).

The present study was limited to areas that actually have been exposed to tenure changes. Obviously many of the factors influencing the results are not directly related to any tenure change, but rather to more general trends and conditions that are universal to much larger areas. It would therefore have been useful to assess also areas not affected by tenure change in order to compare results and provide a better insight regarding which impacts could be attributed to tenure change and which should be attributed to other factors.

Despite of the continued population pressure, currently standing at 132 people per km² in the Amani plateau, the study seems to indicate obvious positive changes in terms of forest cover and forest stocking, at least in parts of the reserve. This could be related to a better compliance on rules and regulations regarding management in the area, following the tenure changes. The impact of the tenure changes on the livelihood for those living in the adjacent areas, however, has not been investigated in the present study. Research on livelihood issues is thus required in order to provide a deeper and balanced understanding of all impacts, not only those related to the biological resources.

CONCLUSION

The aim of the present study was to evaluate the impact of changes from private to state tenure on forest resources in the Amani Nature Reserve. Although the results were somewhat ambiguous, and the changes in forest resources were varying between the different former blocks, important evidence of positive impacts as a result of the tenure changes was identified. This is in line with the main aim of establishing nature reserves focusing on conservation values. More research, however, is required regarding the impact of tenure changes on the livelihood for those living in adjacent areas of the nature reserve.

ACKNOWLEDGEMENTS

The funding of this study was from the Tanzania – Norway NUFU Programme (2007–2011) under the project titled “Assessing the impact of forestland tenure changes on forest resources and rural livelihoods in Tanzania”, a cooperation between the Department of Forest Mensuration and Management, Sokoine University of Agriculture, Tanzania and the Department of Ecology and Natural Resource Management, Norwegian University of Life Sciences. Special thanks to Iddi Rajabu, The Late Corodius Sawe, Henry Kayeye and Norbert Cordeiro for their technical support. Finally, we are thankful to the editor and two anonymous reviewers for their useful comments and suggestions.

REFERENCES

- AFIMP 1988. Amani Forest Inventory and Management Plan. East Usambara Mountains. FINNMAP Press, Helsinki, Finland.
- ANR 2007. Amani Nature Reserve General Management Plan 2007–2012. Ministry of Natural Resources and Tourism, Tanga, Tanzania.
- Blomley T., Pfliegner K., Isango J., Zahabu E., Ahrends A. and Burgess N. 2008. Seeing the wood for the trees: an assessment of the impact of participatory forest management on forest condition in Tanzania. *Oryx* **42**: 380–391.
- Burgess N.D., Butynski T. M., Cordeiro N.J., Doggart N.H., Fjeldsa J., Howell K.M., Kilahama F.B., Loader S.P., Lovett J.C., Mbilinyi B., Menegon M., Moyer D.C., Nashanda E., Perkin A.,

- Rovero F., Stanley W. T. and Stuart S. N. 2007. The biological importance of the Eastern Arc Mountains of Tanzania and Kenya. *Biological Conservation* **134**: 209–231.
- Chamshama S.A.O., Mugasha A.G. and Zahabu E. 2004. Stand biomass and volume estimation for Miombo Woodlands at Kitulungalo, Morogoro, Tanzania. *Southern African Forestry Journal* **200**: 59–69.
- EUCAMP 2002. Completion Report of the Phase III (1999–2002). Ministry of Natural Resources and Tourism, Tanga, Tanzania.
- FBD 2009. Eastern Arc Mountains Strategy: Main strategy document. Ministry of Natural Resources and Tourism, Dar es Salaam, Tanzania.
- Frontier Tanzania 2001. Amani Nature Reserve: A biodiversity survey. EUCAMP Technical Paper No. 52. Dar es Salaam, Tanzania.
- Gereau R.E., Luke W.R.Q., Kindeketa W.J., Bodine S., Festo L., Kibure O.A., Laizer G.S., Schatz G., Hilton-Taylor C. and Maunder, M. 2010. Plant conservation assessment in the Eastern Arc Mountains and Coastal Forests of Tanzania and Kenya. [<http://www.mobot.org/MOBOT/Research/tanzania/cepf.shtml>]_site visited on 7/5/2010.
- Hall J., Burgess N.D., Lovett J., Mbilinyi B. and Gereau R. E. 2009. Conservation implications of deforestation across an elevational gradient in the Eastern Arc Mountains, Tanzania. *Biological Conservation* **142**: 2510–2521.
- Hamilton A.C. 1989. The climate of the East Usambaras. Pp. 97–102 in Hamilton A. C. and Bensted-Smith R. (eds). *Forest conservation in the East Usambara Mountains, Tanzania*. IUCN –The World Conservation Union and Forest Division, Ministry of Lands, Natural Resources and Tourism, Dar es Salaam, Tanzania.
- Hughes A.R., Byrnes J.E. and Stachowicz J.J. 2007. Reciprocal relationships and potential feedbacks between biodiversity and disturbance. *Ecology letters* **10**: 849–864.
- IUCN. 1990. *Biodiversity in Sub-Saharan Africa and its Islands: Conservation, management and sustainable use*. IUCN Press, London, UK.
- IUCN. 2010. IUCN Protected Areas Categories System. [http://www.iucn.org/about/work/programmes/pa/pa_products/wcpa_categories/]. Date accessed 06/05/2010.
- Kajembe G.C., Ngaga Y.M. and Chamshama S.A.O. 2008. Participatory forest management in Tanzania: Opportunities, challenges and lessons Learned. [http://www.CERES_formagmt/site.html] site visited on 9/12/2008.
- Krebs C.J. 1999. *Ecological Methodology*. Second Edition. Addison-Wesley Longman Inc., California, USA.
- Luoga E.J., Kajembe G.C., Shemweta D.T.K., Zahabu E., Mwaipopo C.S. and Kweka D.L. 2005. Assessment of Tree Stocking and Diversity for Joint Forest Management (JFM) in Nkweshoo Village Forest Management Area, Kilimanjaro, Tanzania. *Forests, Trees and Livelihoods* **15**: 259–273.
- Mathew M.M., Munjuga M.R., Ndangalasi H.J. and Cordeiro N.J. 2009. Aspects of the floral and fruit biology of *Allanblackia stuhlmannii* (Clusiaceae), and endemic Tanzanian tree. *Journal of East African Natural History* **98**: 79–93.
- Mbilinyi B.P., Malimbwi R.E., Shemwetta D.T.K., Songorwa A.N., Zahabu E., Katani J.Z. and Kashaigili J. 2006. Forest area baseline for the Eastern Arc Mountains. Forest and Beekeeping Division, Dar es Salaam, Tanzania.
- Munishi P.K.T., Shear T.H., Wentworth T., Temu R.P.C and Maliondo S.M.S. 2004. Sparse distribution of pattern of some plant species in two Afromontane rain forest of Eastern Arc Mountains of Tanzania. *Tanzania Journal of Forestry and Nature Conservation* **75**:74–90.
- Newmark W.D. 1998. Forest area, fragmentation, and loss in the Eastern Arc Mountains: Implication for the conservation of biological diversity. *Journal of East African Natural History* **87**: 29–36.
- Newmark W.D. 2004. Gold mining threatens biodiversity in the East Usambara Mountains, Tanzania: In Conservation news. *Oryx* **38**:03. 254.
- Reyes T., Luukkanen O. and Quiroz R. 2006. Small Cardamom – Precious for People, Harmful for Mountain Forests: Possibilities for Sustainable Cultivation in the East Usambaras, Tanzania. *Mountain Research and Development* **26**: 2. 131–137.

- Torras O. and Saura S. 2008. Effects of silvicultural treatments on forest biodiversity indicators in the Mediterranean. *Forest Ecology and Management* **255**: 3322–3330.
- Uhuru L.M. 2008. Impact of conservation and development intervention on livelihoods and forest resources management in Pangani river basin: A case of Muheza District, Tanzania. MSc. thesis, Sokoine University of Agriculture, Morogoro, Tanzania.
- URT. 1998. National Forest Policy. Ministry of Natural Resources and Tourism. Government Printers, Dar es Salaam, Tanzania.
- URT. 2003. Resource Economic Analysis of Catchment Forest Reserves in Tanzania. Forest and Beekeeping Division, Dar es Salaam, Tanzania.
- URT. 2009. National Framework for Reduced Emissions from Deforestation and Forest Degradation (REDD). Dar es Salaam, Tanzania.
- Vihemäki H. 2009. Participation or further exclusion? Contestations over forest conservation and control in the East Usambara Mountains, Tanzania. PhD dissertation, University of Helsinki, Helsinki, Finland.
- Woodcock K. A. 1995. Indigenous Knowledge and Forest Use: Two case studies from the East Usambaras, Tanzania. EUCFP Technical Paper No. 22, Tanga, Tanzania.
- Zahabu E., Eid T., Kajembe G.C., Mbwambo L., Mongo C., Sangeda A.Z., Malimbwi R. E., Katani J.Z., Kashaigili J.J. and Luoga E.J. 2009. Forestland tenure systems in Tanzania: An overview of policy changes in relation to forest management. INA-Fagraport No. 14, Department of Ecology and Natural Resource Management, Norwegian University of Life Sciences, Aas, Norway.