



## Valuing the Arc Programme

### Annual report to the Leverhulme Trust for 2010

#### Overview and objectives

Valuing the Arc (VtA) is an interdisciplinary programme with two broad parts.

Part A – theoretical review. This part of the programme aims to develop and publish a broad conceptual model for undertaking an 'ecosystem services approach' to conservation. This aims to be generic and applicable globally. This stage in the programme has now been completed.

Part B – Eastern Arc case study. The second part aims to test the conceptual model across a system that is important for biodiversity conservation and ecosystem service delivery. In this part of our work we focus on the Eastern Arc Mountains (EAMs) of Tanzania, using a series of service-specific modules to measure, model and map the production, flow and value of services generated by the EAMs both now and under a range of plausible scenarios of future development..

Both parts of the programme are producing high level scientific papers, organizing workshops and seminars, and generating technical materials that are being fed into the policy process in Tanzania and beyond. The programme is also helping build capacity on ecosystem service (ES) conceptualization, mapping and valuation in five British and two Tanzanian Universities, as well as within the WWF network. Ideas developed are being promoted within other key collaborators in the USA-based Natural Capital Project.

The first section of this report presents an overall summary of the main activities and findings in 2010. This is followed by a more detailed section on the development of each module of work, presented as an Appendix. .

## **Brief overview of progress of the Valuing the Arc programme**

### **Summary**

Most of 2010 was spent completing outstanding field work, analyzing data, and working towards the finalization of the respective biophysical and socio-economic models describing the production, flow, use and value of services across the EAMs. During this period fieldwork was undertaken for the biodiversity module (April to June), the tourism module (August), and the carbon module (July to November).

We made good progress on the majority of modules over the course of 2010, and several (such as carbon and tourism) are nearing completion. Certain modules such as hydrology, are still proving to be challenging, although substantial progress was made during 2010 with the appointment of new staff and the acquisition of missing data sets. All service-related modules are generating spatially-explicit models describing their current production across the EAMs, which we can then link to our scenarios of change to explore how development decisions may influence the provision of ecosystem services into the future. Our GIS database continues to be refined and represents the most comprehensive such dataset for this region of Tanzania. As a result of the VtA analysis a new boundary map of the EAMs has been derived according to quantitative rules for landform classification, data on the distribution of mountain vegetation and the established phytogeography of the region. This new boundary map will be used by all ES modules in the analysis of biophysical associations.

Because most modules had not yet attained a stage where results were presentable, few presentations were delivered in 2010 (in contrast to previous years, when many conceptual presentations were given). This will be addressed in the final year of the programme, both in the UK and also in Tanzania, through a series of dissemination activities.

Eleven VtA publications appeared in the peer-reviewed literature in 2010, adding to those already published by the programme (23 prior to 2010), and there are currently 13 manuscripts published or in press for 2011. It is expected that the writing up will continue throughout the final year and beyond the formal end of the programme, so that the final total of scientific publications will be in excess of 50.

The VtA programme continues to enjoy a high academic profile for its work in ES evaluation, and to contribute at the policy level in Tanzania - for instance by providing guidance and data for helping with the country's early implementation of the UN's REDD (Reduced Emissions from Deforestation and Degradation) scheme .

The first half of 2011 will be spent finalizing each of the ecosystem service modules, to enable the eventual synthesis of all modules in the second half of the programme's final year..

In brief the key achievements of each of our modules in 2010 have been as follows:

## **Carbon**

The remaining fieldwork was successfully completed during 2010. Plots that were established during the early part of this programme were re-sampled to estimate carbon sequestration. An extensive literature review was completed to obtain values of carbon storage for the 5 carbon pools for each land cover type in the study area – the results were incorporated into the scenarios and successfully published (Swetnam et al., 2011). Results were also used to illustrate a new approach to estimating the costs associated with implementing REDD (Fisher et al. in press). Some of the sample plot data were used to produce vegetation model outputs that run inside climate change models.

## **Timber**

The timber model progressed, with work focusing on a plan for building a spatially-explicit model of stocks of timber in VtA forests. The challenge has been in obtaining data on growth rates for the different timber tree species and in estimating sustainable extraction levels. Addressing these problems will be the main focus of work on this module over the final year.

## **Hydrology**

Biniam Ashagre was employed as the new hydrology PDRA in the first half of 2010. As a result progress on the hydrology module has accelerated. In particular, comparisons of different Potential Evapotranspiration methods were performed for the Kilombero catchment in the study area. Rainfall gauge and river flow data were collated and calculated, and soil hydrological parameters were investigated and substituted with pedotransfer functions where necessary.

## **Non-Timber Forest Products (NTFPs)**

Household survey datasets on NTFP collection were cleaned and merged. Household production functions were estimated for charcoal, firewood, and thatch, reflecting the main NTFP's collected from the EAMs. A novel technique to account for distance to available forest and woodland was developed and applied.

## **Biodiversity**

The ranges within the EAMs of all endangered and all endemic birds, amphibians, and mammals have now been mapped. Reptiles have proved difficult to map and will probably be excluded from the final analysis as a result. Over the coming year the maps for the other three groups will be compiled to make a biodiversity layer for species of conservation concern, which will contribute to a systematic conservation plan for the EAMs.

## **Tourism**

Further fieldwork was found to be necessary in order to complete a dataset of foreign and national visitor numbers to the EAM blocks. During August 2010 J. Bayliss visited the areas not previously visited through the VtA. These data were then used to generate a series of Net Present Values of producer surplus and profit for each EAM block. During 2011 these results will be refined to account for variation in the relative importance of nature as a reason for visitor attraction to the EAMs before a series of GIS data layers are produced to describe variation in the value of nature-based tourism across the EAMs.

## **Conservation costs**

Further fieldwork was undertaken in Tanzania during 2010 which focused on interviewing protected area managers and collating management plans for their sites in order to identify the current conservation investments as well as the costs of effective conservation. These data were then used to build a spatially-explicit model of the management costs of EAM protected areas, which explained 66% of the variation as a function of population pressure and reserve type. In terms of damage costs a comprehensive literature review was started, to explore the relationship between distance to protected area and damage level. This will be finalized in 2011 which in the absence of more detailed data will enable a simple rule-of-thumb to be developed that estimates damage costs around protected areas in EAMs. Last, the previous data collected on opportunity costs proved inadequate for statistical modeling (either because of poor farmer recall or because costs are driven by variables which we have not mapped), and so instead we are now exploring a new approach using published maps of crop yield is being explored to derive a modeled surface of opportunity cost.

## **Degradation**

Following the completion of the relational database (of 1057 degradation transects) at the end of 2009 our degradation models explained only 20% of the deviance found in the evaluation data set. 2010 saw an improvement in this situation with the degradation models achieving a relatively good explanatory power under cross validation. This model improvement is largely down to a renewed cleaning of the database with a strict rule-based approach which excluded any transects with potentially doubtful coordinates, combined with and the inclusion of new predictor variables.

## **GIS and scenarios**

Technical support and GIS modelling assistance was given to all the modules in 2010, particularly carbon, NTFP and hydrology. Our two overarching scenarios of plausible future change were revised to include improvements to accessibility, climate, and soil data, which resulted in a new set of land cover layers to support further modeling. The MODIS Burn Area data were processed to create a map of probability of fire occurrence for input into the biodiversity and carbon modules. A map layer depicting road access has proved to be more problematic as the reality on the ground is at odds with Tanzanian government plans for road improvement. At present this layer has been left unchanged. Last, a new EAM outline boundary was derived based on a series of quantitative rules for landform classification, the

distribution of mountain vegetation, and the established phytoecography of the region (Figure 1). This has been accepted for publication (Platts et al. in press).

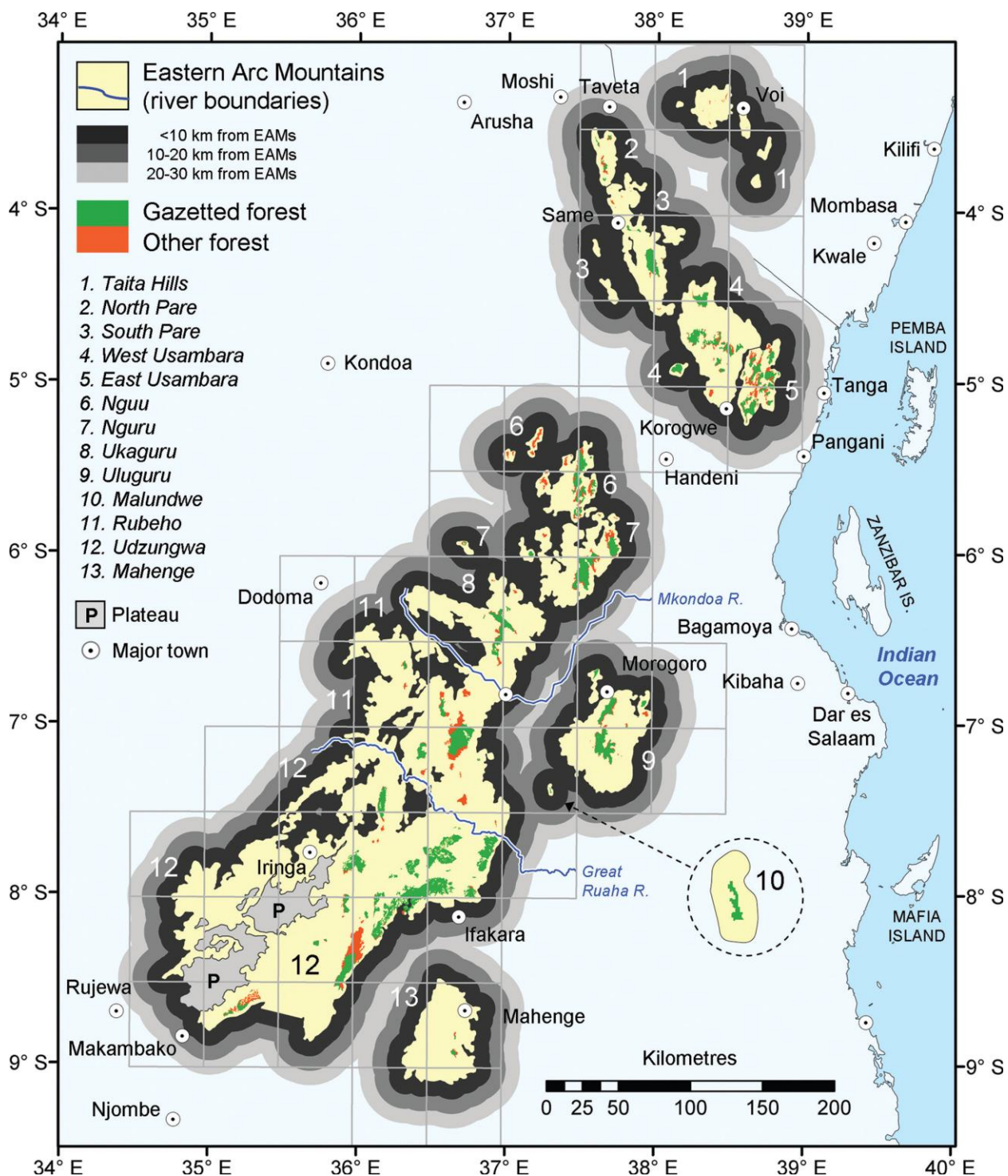


Figure 1. New Ecoregion boundaries, overlaid with forest distributions and protection status.

**VtA module progress, problems (both 2010), and expectations (2011)**

<b>Module</b>	<b>Progress during 2010</b>	<b>Problems in 2010</b>	<b>Expectations in 2011</b>
<b>Carbon</b>	Outstanding fieldwork was completed. Data on carbon storage in 2500 sample plots were processed. An extensive literature review of carbon storage for 5 carbon pools in the EAM was also completed. Tier1 and Tier 2 models are now complete.	Due to a lack of raw data it will only be possible to create the Tier 3 model for the forest and woodland categories.	Create Tier 3 model for forest and woodland to. Complete all remaining aspects of the analysis and write up.
<b>Timber</b>	The timber module has progressed with a concrete plan for a spatially explicit model of stocks of timber in VtA forests.	This module suffered in staff input time in 2010 due to other modules requiring greater resource allocation.	Append gross values to timber stocks as a starting point to understand the current value of the flow of timber leaving the EAMs, and attempt to show where the benefit of timber extraction accrues on the landscape.
<b>Hydrology</b>	Comparison of different potential evapotranspiration methods, preparation of river flow curves, comparison of Soil and Terrain map for Tanzania (SOTER), refinement of the land use data required as input for the SWAT models.	Progress hindered due to data availability and quality.	Calibrate and validate SWAT for Ruvu. Set up, calibrate and validate SWAT for Kilombero. Write up results in a series of scientific papers.
<b>NTFPs</b>	Household survey data cleaned and merged. Household production functions estimated for charcoal, firewood, and thatch for EAMs. Technique developed to account for distance to available forest/woodland.	Data not sufficient to build a reliable model of pole extraction.	Link carbon values at NTFP collection source to REDD compensation and extrapolation to carbon stocks. Link NTFP use to poverty rates.
<b>Biodiversity</b>	Distribution data on endangered and endemic birds, amphibians, and mammals were collated and mapped.	Reptiles proved to be difficult to map and will probably be excluded from final analysis.	Combine distribution maps to make a biodiversity layer for species of conservation concern in the EAMs.
<b>Tourism</b>	Field work was undertaken to complete the data set for EAMs previously not visited. A model was developed which produced two Net Present Values (NPVs) for producer surplus and profit at the EAM block level.	Certain parameters were supplemented from tourism work based in Peru in order to calculate the two NPVs. These parameters will be estimated using African values.	Finish this model in the first half of 2011. A methodology has now been agreed upon which will result in a series of refined NPVs represented through a GIS. A predictive model will also be investigated.
<b>Conservation costs</b>	A modeled surface of Protected Area management costs was developed. A literature review on damage costs by wildlife was completed.	It proved impossible to construct an opportunity cost model using the data collected on farm rents.	Use data on patterns of biodiversity in the EAMs to build a combined biodiversity layer. Build a model of opportunity costs using data collected through fieldwork

			combined with published maps of maize and bean yield.
<b>Degradation</b>	The degradation model now achieves a relatively good explanatory power under cross validation.	Model improvement is as a result of a strict rule-based approach excluding transect data with suspect coordinates.	Test the model's predictive accuracy on independent data sets. Use it to examine the impact of degradation on floristic diversity and carbon storage.
<b>GIS and scenarios</b>	Technical support and GIS modelling assistance was given to all modules - particularly carbon, NTFP and hydrology. A new map was derived of the exact placement of EAM boundaries according to quantitative rules for landform classification and the established phytogeography of the region (Figure 1).	Problems relate to the acquisition and quality of basic GIS data sets.	Finalize spatially explicit modeled surfaces of the ecosystem services. Assist in valuation of these services. Extend scenarios (by toggling policy triggers related to water PES and REDD+) and use service models to map out consequences for ecosystem services.

## Staffing developments

### Programme coordination

At the beginning of 2010 Neil Burgess accepted the position of Professor at the University of Copenhagen. As a result Julian Bayliss took over the responsibility of general programme coordination. Neil Burgess will remain involved with the writing elements of the programme until its end. In Tanzania, Shadrack Mwakalila continued in his position as coordinator within the WWF office in Dar es Salaam. The work of University of Dar es Salaam was coordinated by Felix Mtalo and that of Sokoine University of Agriculture by Seif Madoffe.

### Hydrology

During 2010 Biniam Biruke Ashagre was employed as the new PDRA on the hydrology module replacing Celina Smith who left the programme in March 2009.

### Non-timber, timber and forest degradation

Marije Schaafsma was employed through UEA to replace the position previously occupied by Sian Morse-Jones to develop the NTFP model and the valuation of each service. Brendan Fisher (employed on the programme until 2009) has continued to be involved from his new position at Princeton.

### PhD students

There were no new PhD students recruited in 2010.

### Masters and bachelors students

There have been a total of 7 students trained at Sokoine University of Agriculture (SUA) through the VtA programme. These are Joseph Makero (Timber), Kilonzo Muhuji (NTFPs), Christina Mohamedi (Governance), Deo Shirima (Carbon), Francis Shirima (Carbon), Amanzi Nurman (Governance), and Doreen Naza Emanuel (Tourism).

## **Significant workshops, conferences, meetings, and events**

The programme held a series of internal workshops and meetings and presented the programme's work at several conferences during 2010.

### **Meetings and presentations in Tanzania**

There were two meetings in Tanzania where VtA results were presented:

Shadrack Mwakalila presented results of the VtA programme at the UN-REDD/NAFORMA-Stakeholders' workshop (3-5 February) on "Enhancing Tanzanian capacity to deliver short and long term data on forest carbon stocks across the country".

Shadrack Mwakalila also presented at the Post Copenhagen workshop and the commemoration of Africa Environment Day (3-4 March) on "Assessment, valuation, mapping and monitoring carbon stocks at sub-regional level: Supporting REDD readiness in TANZANIA."

### **Meetings and presentations outside Tanzania**

There were numerous small meetings held in the UK to discuss progress within individual ES model development.

More substantially, a programme progress meeting was held on 17 June in Cambridge with participants from UEA, Cranfield, and Cambridge universities to discuss progress on NTFPs, hydrology, tourism and valuation.

On 15-17 September a larger regional VtA meeting was held at the University of Cambridge with participants from UEA, Cranfield, York, WWF US, and the US-based Natural Capital Programme. The purpose of this meeting was to discuss challenges of integrated modeling and also to think about the delivery of the programme in the final year.

Brendan Fisher presented a talk on the "Real costs of REDD – from opportunity costs in mechanized logging and industrial agriculture systems to replacement costs in subsistence regimes" at the Association of Tropical Biodiversity and Conservation (ATBC), 20 July, Bali, Indonesia.

Brendan Fisher also gave a presentation on "Conservation and human welfare" at a meeting on Biodiversity and the UN Millennium Development Goals in Frankfurt, 1–3 December.

Ian Bateman presented work developed in association with Sian Morse-Jones at WCERE conference in Montréal (30 June) in a talk entitled "[Testing the theoretical consistency of stated preferences for tropical wildlife conservation](#)".

### **Additional activities related to the VtA outputs**

Ruth Swetnam successfully applied for funding from the Student Conference on Conservation Science for an internship for a Chinese PhD student to attend the conference and to spend a month in the UK. Miss Zhuangfang Ye (Xishuangbanna Tropical Garden Research Institute) is a PhD student working on the valuation and spatial modelling of rubber plantations in South-west China. During the internship work focused on developing valuation methods through a GIS modeling framework, which is of benefit to the VtA programme.

**Timetable – summary of personnel and activities in 2010**

<b>Item</b>	<b>Jan- Mar10</b>	<b>Apr- Jun10</b>	<b>Jul- Sep10</b>	<b>Oct- Dec10</b>
<b>Part A - Theoretical Review</b>				
Economics postdoc (UK)				
Drafting papers				
<b>Part B - Eastern Arc Case Study</b>				
<i><b>Student progress</b></i>				
Carbon post doc (UK)				
Carbon PhD (UK)				
Carbon Masters (TZ)				
Timber Masters (TZ)				
Hydrology postdoc (UK)				
Hydrology postdoc (TZ)				
NTFP Masters (TZ)				
Governance Masters (TZ)				
Animal biodiversity PhD (UK)				
Plant biodiversity PhDs x2 (KITE)				
Tourism Masters (TZ)				
Valuation PhD (TZ)				
<i><b>Module development</b></i>				
Modelling carbon storage				
Modelling timber volumes and values				
Modelling hydrological flows and values				
Modelling NTFP amounts and values				
Socio-economic scenarios (TZ and UK)				
Modelling plant and animal distribution				
Climate change scenarios (UK)				
Modelling tourism				
Biodiversity existence values (UK)				

## Plans for 2011

### Part A – Theoretical Review.

A conceptual model has now been developed and the work completed for this section of the programme.

#### *Overall goals.*

A series of scientific papers has already been published as a result of the theoretical review and conceptual model (see publications).

Part B – Eastern Arc Case Study. For the majority of ES modules work is on schedule and progressing well. Detailed workplans have been developed and in broad terms these are as follows:

#### *Overall goals.*

This is the final year of the VtA programme. It is hoped that by the middle of 2011 all biophysical and socio-economic modeling will be completed. Work will then turn to running these models using the modified land-cover and socio-economic surfaces describing our scenarios, and thereby testing the impact of these alternative futures on ecosystem service provision across the Arc. Suitable dissemination activities will need to be planned both in the UK and Tanzania towards the end of the year to deliver the results of the programme.

#### *Cambridge University.*

The team will continue to compile and integrate available GIS data to underpin the analyses of individual services that forms the core of the case study work. We will increasingly work on cross-cutting analyses that integrate across services and that link service models to scenarios of future change. The team will also continue to produce papers, coordinate the programme with partners in Tanzania and the UK, and maintain the collaboration with the York Institute for Tropical Ecosystem Dynamics (KITE) and the Natural Capital Project. For 2011 the key objectives are:

- 1) To finalise the spatially explicit modelled surfaces of the ecosystem services
- 2) To assist UEA in the valuation of these surfaces
- 3) To assess the potential impact of changes using the scenario maps already developed.
- 4) To work out the impacts of these changes in terms of the spatial and social distribution of winners and losers.
- 5) To contribute to the final reporting of the results and their dissemination at suitable events in Tanzania and the UK .

#### *Cranfield University.*

The Cranfield team will continue to develop the hydrology module. The objectives for 2011 are:

- 1) To calibrate and validate the SWAT model for the Ruvu catchment before April
- 2) To write papers on the calibration, validation and sensitivity analysis of SWAT for the Ruvu catchment

- 3) To start setting up the SWAT model for the Kilombero catchment in March
- 4) To calibrate and validate the SWAT model for the Kilombero catchment before June
- 5) To write papers on calibration, validation and sensitivity analysis of SWAT for the Kilombero catchment
- 6) To calibrate a simple EAM-wide hydrological model developed in Cambridge, using available flow data.
- 7) To use the SWAT model to investigate different scenarios and interpret the results
- 8) To apply these scenarios to the EAM-wide hydrology model.
- 9) To prepare papers according to the results and preparing the final report before the end of July

*University of East Anglia (UEA).*

Objectives for 2011 include relating carbon values involved at product source in NTFP collection to REDD compensation and carbon stocks, and linking NTFP use to poverty rates. NTFP models developed through the VtA study also need to be compared with those from other studies for cross validation. UEA will coordinate the valuation of the ES models.

*York University.*

Over the course of 2011 the team in York will further develop the carbon module in collaboration with the team in Leeds. The VtA team at York will also collaborate with KITE over the completion of several scientific papers which span both programmes.

*Leeds University.*

The team in Leeds will continue working on the development of the carbon module to produce a tier 3 model for woodland and forest. A tier 4 model will also be investigated. No further fieldwork is proposed for 2011, and all the remaining aspects of the analysis will be completed and written up.

*University of Dar es Salaam (UDSM).*

VtA participants from UDSM will contribute to the write up and analysis of results, and play a lead role in the policy dissemination of these results in Tanzania in the latter part of 2011. Masters and PhD students will continue their work where applicable.

*Sokoine University of Agriculture (SUA).*

VtA participants from Sokoine will contribute to the write up and analysis of results, and play a lead role in the policy dissemination of these results in Tanzania in the latter part of 2011. Masters and PhD students will continue their work where applicable.

*WWF Tanzania Country Office (TCO).*

The TCO will continue in its role as the main facilitator within Tanzania. During this final year of the programme the TCO will play an important role in the dissemination of the work, especially in the latter half of the year when results will be at a stage ready for policy dissemination within Tanzania. The exact mechanism to deliver these results will be decided by the TCO, WWF US, and Cambridge. It is envisaged that results will feed directly into management plans such as the mechanism for REDD payments in the country. As before, links will also be maintained in the development of the new Forest Policy for Tanzania, and to the implementation of the Water Policy and Water Act.

*KITE programme.*

We will continue to implement our MoU with the KITE programme in York University and thereby support their work while benefitting from the research that they are doing on plant biodiversity patterns, forest degradation patterns, and the impacts of climate change. We will work on collaborative papers on these topics.

*Natural Capital Project.*

We will continue to work with the USA-based Natural Capital Project to complete and publish the results of ecosystem services models in the EAMs. We will look for advice and support from the Natural Capital Project for the dissemination of VtA results in Tanzania.

## Papers and other publications

### 2007

Fisher, B. and R.K. Turner (2007). Valuing the Arc: applying environmental decision-making methodology in Tanzania's Eastern Arc Mountains. *Britain in 2008*, 14.

### 2008

Fisher B., Turner, R.K., Balmford, A., Brouwer, R., Costanza, R., de Groot, R., Farber, S., Ferraro, P., Green, R., Hadley, D., Harlow, J., Jefferiss, P., Kirby, C., Morling, P., Mowatt, S., Naidoo, R., Paavola, J., Strassburg, B., Yu D., and M. Zylstra (2008) Ecosystem services and economic theory: Integration for policy-relevant research *Ecological Applications*, 18(8): 2050–2067.

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## 2011

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- Marshall, A.R. and P.T.K. Munishi, (**in press**) Valuing the Arc: measuring and monitoring forest carbon for offsetting. In: *Theory and Practice of Ecosystem Service Valuation*, eds Kareiva, P., Ricketts, T., Daily, G., Tallis, H., Polasky, S.. Oxford University Press, Oxford.
- Morse-Jones, S., Luisetti, T., Turner R.K. and B. Fisher (**in press**). Ecosystem Valuation: Some Principles and a Partial Application. *Environmetrics*.
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## Web Sites

The Valuing the Arc website ([www.valuingthearc.org](http://www.valuingthearc.org)) has been developed to further disseminate the programme's findings, and is currently maintained by Sian Morse-Jones.

Input has also been made to the Natural Capital Project's website, [www.naturalcapitalproject.org/tanzania](http://www.naturalcapitalproject.org/tanzania).

## **Appendix:**

### **Progress of the Valuing the Arc programme (in detail)**

#### **Part A - Theoretical review**

The theoretical review was undertaken by Prof Kerry Turner, Dr Brendan Fisher, and Dr Sian Morse-Jones at the University of East Anglia and other members of the Valuing the Arc team.

This module was largely completed in 2009 resulting in the publication of 11 peer-reviewed papers and a book chapter (see publications). In addition several more publications have been submitted and more are planned.

The module developed the theoretical framework for the Ecosystem Services Approach (ESapp) resulting in a novel classification and sequential assessment methodology. The former adapts the classification system compiled by the Millennium Ecosystem Assessment team in order to tailor it to the needs of an assessment method that yields economic values for final ecosystem services benefits. The distinction made between intermediate and final ecosystem services is fundamental and helps to guard against double counting error. The sequential approach highlights a set of interpreted steps in the analytical process that results in a set of interrelated estimates of ecological service values. The approach highlights the importance of initiating the natural and social science analysis in a spatially explicit format. On the basis of spatially explicit ecosystem services generation and benefits distribution, the analysis then proceeds to identify environmental changes. To fit into an economic cost-benefit frame, the ecosystem transitions that are identified and evaluated must be 'marginal'. Further steps in the assessment method are designed to take account of non-linearities in the benefits provision and possible threshold (non-convexities) effects. This economic valuation methodology is then encompassed within the overall ESapp framework.

The macro-scale framework includes scenario building and assessment, distributional analysis and the exploration of governance regimes and their influences on ecosystem change and management and livelihood provision. Monitoring and information feedback measures complete the feedback loop with ESapp.

## **Part B - Eastern Arc case study**

The Eastern Arc case study involves the development of a number of ES modules and the progress with each of these over 2010 is outlined in detail below.

### ***Carbon***

The main people involved with the carbon module are Simon Lewis and Simon Willcock (University of Leeds), Jon Lovett and Andrew Marshall (University of York), and Pantaleo Munishi and Deo Shirima (Sokoine University of Agriculture).

The module made good progress in 2010 and is developing as planned. Highlights and achievements for the year were:

- (a) Data from 2500 sample plots was collated and processed enabling estimates of carbon storage spanning the Eastern Tanzania study area to be made.
- (b) Fieldwork was successfully completed and plots examined during the early part of the programme were re-sampled.
- (c) An extensive literature review was undertaken to obtain values of carbon storage for 5 carbon pools for each land-cover type in the Eastern Arc study area; results were incorporated into the scenarios and submitted for publication (Swetnam et al, 2011).
- (d) Carbon module results were also used to estimate the true costs associated with REDD (Fisher et al, in prep.).
- (e) Some of the sample plot data was used to confront vegetation model outputs that run inside a climate change model (called Dynamic Global Vegetation Models, that subsequently operate within Global Circulation Models) for the first time (Doherty et al. 2010).

The permanent sample plots put in by Dr Andrew Marshall were re-measured. The data from all plots are currently being analysed to provide insights into the carbon sequestration (a) among different forests across Tanzania (b) for incorporation into our carbon model, and (c) to facilitate better understanding of the relationships between carbon sequestration and environmental parameters. The collection and processing of the data has taken much of 2010.

The first model that utilised carbon values for this study was known as the Tier 1 model and was produced under the INVEST initiative by our collaborators Taylor Ricketts and Nasser Olwero (Natural Capital Programme). Tier 1 was a relatively simple model relating land use cover to approximate carbon storage values. This model has been improved on by the production of a Tier 2 model in which the carbon storage values are much more applicable to

the study area and also include an element of uncertainty. It is anticipated that, for woodland and forest land cover categories (where data is available), the Tier 2 model will be superseded by a Tier 3 model. The Tier 3 model will involve that creation of a regression model to enable a better understanding of the relationships between carbon storage and environmental parameters. This will be complemented by a Tier 4 model, similar to the Tier 3 model but examining the relationship of carbon sequestration with environmental parameters. Tier 3 and 4 work will take place during 2011.

The Tier 2 carbon model underwent several improvements throughout 2010 and now is completed, with several drafts of a paper having been produced. This model uses carbon values from an extensive literature review as well as the large dataset at our disposal to provide carbon storage estimates for each land-cover found in the study area across 5 carbon pools: aboveground; litter; coarse woody debris; belowground; and soil. Preliminary values from this model have already inputted into several scientific papers (Swetnam et al., 2011 and Fisher et al, in prep). On completion the Tier 2 model will be used with current and past land use maps in order to convey the carbon released due to land use change in the study area over the past century.

The Tier 3 model creation is due to commence in the spring of 2011. The Tier 3 model differs in that it is a regression model able to show differences in carbon storage within each land-use category. However, due to a lack of raw data it will only be possible for this model to be created for the forest and woodland categories. This model will take into account climatic and anthropogenic categories and, using the plot data, will estimate the carbon distribution within the land classes separately as well as providing possible insights into the drivers of the transition between these two categories.

### ***Timber***

The timber module is coordinated by Phil Platts (University of York), Simon Willcocks (University of Leeds), Antje Ahrends (University of York/Royal Botanical Gardens Edinburgh), and Brendan Fisher (formerly University of East Anglia).

The timber module progressed with a concrete plan for a spatially explicit model of stocks of timber in VtA forests. The next task is to append gross values to these stocks as a starting point towards the goal of understanding the current value of the flow of timber leaving the EAMs based on market surveys and the degradation model. As a result we will attempt to identify where the benefit of timber extraction accrues on the landscape, which will most likely be based on population data and some indicator of demand (perhaps proxied by charcoal data).

### ***Hydrology***

The Hydrology module is coordinated by Sue White and Biniam Ashagre (Cranfield University), and Felix Mtalo (University of Dar es Salaam).

Good progress was made on this module during 2010 following the employment of Biniam Ashagre as the new PDRA hydrologist. We are still lacking a more comprehensive and uniform distribution of rainfall measuring stations with available data for the period intended to run the SWAT analysis, which may result in the use of TRMM data as an alternative source.

The main milestones in 2010 were:

- Comparison of different PET (Potential Evapotranspiration) methods for the Kilombero catchment (Penman–Monteith FAO, Penman–Monteith SWAT and Hargreaves approaches) – the result of which were found to be similar.
- Preparation of flowing curve and the calculation of flow for rivers with measured data in the Ruvu catchment.
- Comparison of SOTER (Soil and Terrain) map for Tanzania and soil map developed by Hathout 1983 (chosen because of its clear description of the soil textures and the matching of these soil descriptions within the EAMs).
- 19 different soil units were identified in the Ruvu catchment and a representative soil profile was assigned to each soil unit by selecting the best match, from the different profile (point data), to the soil texture description by Hathout. Soil hydrological parameters were not available so the use of pedotransfer functions were necessary. Pedotransfer functions are empirical equations used to calculate unmeasured soil parameters from easily measured soil textures. These functions are used to estimate available water capacity (the amount of water equal to the difference between field capacity and permanent wilting point), bulk density, saturated hydraulic conductivity, the Universal Soil Loss Equation K factor, and soil albedo.
- Some landuse types (plants) in the Ruvu catchment were not considered in the SWAT-Crop database. Parameters describing different eco-physiological properties of the plants were collected through a literature review to build a database.

### ***Non-Timber Forest Products (NTFPs)***

This module is being developed by Kerry Turner, Marijje Schaafsma, Brendan Fisher and Sian Morse-Jones from the University of East Anglia (UEA).

NTFP datasets were collated, cleaned and formatted for modeling and merged with household survey data on NTFP collection. Seven secondary datasets were pooled to provide a single master dataset for the valuation models. A novel technique to account for distance to available forest and woodland was developed and applied. However the data were not sufficiently reliable to estimate a robust pole extraction model. Household production functions were estimated for charcoal, firewood and thatch, reflecting the quantity of different NTFPs collected from the Eastern Arc Mountains. The main challenges involved interpreting the secondary datasets and in standardizing the data to create consistent variables. The final pooled dataset covers approximately 2000 households in 75 villages across EAMs.

Subsequently, these models were used to estimate the total quantity of NTFPs collected (by all households) and the economic value of this annual flow. The results were mapped, showing spatial variation in NTFP quantities and values.

### ***Biodiversity***

The biodiversity module is coordinated by Kim Howell (University of Dar es Salam), Jon Green (University of Cambridge), Phil Platts (University of York / University of Cambridge), and Neil Burgess (University of Copenhagen, University of Cambridge), with work on the existence value of biodiversity led by Sian Morse-Jones (University of East Anglia).

The distribution of endangered endemic birds, amphibians and mammals was collated and mapped. Unfortunately reptiles proved to be difficult to map accurately and are likely to be excluded in the final analysis. These maps use knowledge of the species' geographic range (extent of occurrence) and habitat preferences (from experts and literature) and ascribe habitat suitability scores to the study area, constrained by the known extent of occurrence. These have been found to be a cost effective and defensible way to increase the resolution of species distribution maps using limited data.

These will be compiled to make a biodiversity layer for species of conservation concern which will input into the biodiversity component of a systematic conservation plan.

### ***Tourism***

The module is currently being coordinated by Douglas Yu (formally of the University of East Anglia), Jafari Kidegesho (Sokoine University of Agriculture), and Julian Bayliss (University of Cambridge).

Visitor numbers to lodges and hotels from EAM blocks that had previously not been visited were collected to complete the data set initially started by Sana Okayasu for her Master's degree on tourism in the EAMs. These data were employed to produce two NPV's of Producer Surplus and Profit over a 25 year period for Total visitors, Tanzanian visitors, and Foreign visitors to each hotel/lodge visited, and subsequently summarized at the EAM block level. These two NPV's were then calculated again using a range of discount rates and fixed profit margins to model for different economic scenarios. The development of a spatially explicit predictive model will be investigated using the range of NPVs generated at the hotel/lodge level and possible drivers such as biodiversity, road access, forest cover etc.

### ***Costs of conservation***

This work is being led by Jonathan Green (University of Cambridge), in coordination with Andrew Balmford (University of Cambridge) and Neil Burgess (University of Copenhagen), and focuses on acquiring site-specific data and then building EAM-wide models of three elements on cost.

- a) Opportunity cost: 3 months were spent conducting fieldwork in the EAM to gather data on farm rents. These data were used to establish the problems and variability that farmers face in crop production and to show the relative importance of different food crops in this area. However, it proved impossible to construct a model based on spatially explicit predictor variables. Ways are currently being explored in which collected data can be combined with published maps of maize and bean yield for East Africa to derive a modeled surface of opportunity cost.
- b) Damage cost: A literature review of the relationship between distance to protected area and damage level is currently being undertaken. The results of this review will be combined with information on which species cause most problems in the EAM (from fieldwork data), which will hopefully enable the development of a simple rule of thumb that describes wildlife damage costs around protected areas in the EAM.
- c) Management cost: Two months were spent visiting protected area managers and collating management plans in order to establish how much money is spent currently and how much money is needed in order to achieve effective conservation. This enabled the development of a spatially explicit model of the management costs of conservation.

### ***Degradation***

The degradation module is being developed by Antje Ahrends (formally University of York, now Royal Botanical Gardens, Edinburgh) with assistance from Ruth Swetnam (University of Cambridge) and Phil Platts (University of York / University of Cambridge).

Progress has been good in this module and the degradation models now achieve a relatively good explanatory power under cross validation. This is largely due to cleaning the database with a strict rule-based approach to analyse the transect data, and the inclusion of new predictor variables.

Objectives for 2011 are to test the model predictive accuracy on an independent dataset and to further predict the impact of degradation on floristic diversity and carbon storage, using the vegetation plot database.

### ***GIS and scenarios***

This component is largely supervised and delivered by Ruth Swetnam (University of Cambridge), in collaboration with Brendan Fisher (formerly of the University of East Anglia) and others.

Technical support and GIS modelling assistance has been given to all the modules in 2010 especially carbon, NTFP and hydrology. A wide range of spatially derived variables have been extracted from the GIS database for villages in and around the EAM in order to model resource extraction from forest reserves and surrounding land. This work has been ongoing from 2009 as it is subject to constant revision by the programme economists as they tackle the complexities of modelling NTFP extraction from the landscape of the EAM. During the earlier part 2010 a new dataset of charcoal sale values along the road network of Tanzania was created to produce preliminary models of price / distance. These data were then refined and developed further to provide useful information for resource valuation.

For the hydrology module a method was devised to allocate crop types to the landcover agricultural categories using the crop proportions detailed in the ward summaries. This involved spatial sampling and data manipulation. This has led to the creation of a more detailed cropping map in the Ruvu and Sigi basins to feed into the hydrological modeling.

In response to progress on the original objectives for 2010 as outlined in the last report:

1. The MODIS Burn Area was processed to produce a probability surface of fire occurrence, although it has not yet been utilized by the carbon group.
2. The two scenarios were revised to include improvements to accessibility, climate, and soil data following the VtA programme meeting in September, and the scenario maps have been recreated using these new inputs.
3. A future population map was created using the population surface originally created for the programme and combined with district specific population growth rates.

Roads surface projections proved to be more problematic because planned road improvements do not necessarily happen as planned and there are often long delays. On this basis the road network was left unchanged to reflect the reality of access rather than the TZ government's aspirations about infrastructure improvements.

4. Assistance was given to create a spatially explicit surface of NTFP extraction with additional GIS support from Paulette Posen (UEA) who has been able to work directly with Marijje Schaafsma.

5. Further work was undertaken on the landcover map to ensure that it reflects recent changes in forest use mapped by Boniface Mbiliyini for the EAM blocks. At present the degraded forest parcels have been mapped as a separate layer to be used when appropriate in the models.

The VtA database has continued to expand over the past year and is still the most comprehensive set of GIS database in existence for this part of eastern Tanzania. The scenarios module has moved forward with generating several spatially explicit maps of land cover change for the year 2025. Objectives for 2011 are to attempt to create a series of maps by toggling policy triggings related to water PES and REDD+.