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Decision support system for balancing ecosystem services at the landscape scale: Petri nets modelling application

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Abstract: The challenges of balancing Ecosystem Services (ES) at the landscape scale to enhance the ecological performance of communities are leading to increasing land degradation, especially from agro-forest landscapes. Therefore decision support systems are needed for policy measures for preserving ES and to contribute towards environmental sustainability. This can be a potential when stakeholders in landscape community are given incentive to motivate them to participate in sustainability schemes.

This paper analyses parameter for balancing ES at the landscape scale with particular focus on agro-forest landscapes in Kolkwitz community in the Spreewald region. A graphical modelling framework with Petri net is used to structure variables for estimating changes in ES for decision support systems on strategy development. It shows how the modelling approach can couple sustainability scheme with incentives to involve multi-actors in participating in preservation of ES using a Community-based Financial Participation framework. The modelling approach is discussed in more details.

Key words: *decision support system, balancing ecosystem services, agro-forest, Petri nets, Kolkwitz*

Introduction

The natural environment can be in steady state, when its processes and functions are in balance, which lack of such balance in many landscape have resulted in land degradation (Poff, Zimmerman 2010; Bauer, Stringer 2009). Land degradation has been a decision for a long time, with a number of conferences and workshop on this topic (Bauer, Stringer 2009). But unfortunately there have been continuously increases of land degradation, especially in agricultural and forest landscapes, which can be seen from the negative consequences on the environment such as desertification, drought, water shortages, floods and climate change (Poff, Zimmerman 2010; Urban 2009; Gontier et al., 2006; Grimm et al., 2008). This shows that environmental balancing is not carryout in activities taking place within landscapes that threatened their ecological performance (Urban 2009). The health of the natural environment depends on changes in the balance of

ES at the landscape scale that also influence the ecological performance leading to a sink (degradation) or improvement. For instance in most landscape, agro-forestry is one of the largest land use activity due to continuous intensification of agricultural activities and if not properly managed will lead to land degradation (Chamberlain et al., 2000; Kleijn, Sutherland 2003). Many reports from studies on agro-forest landscape on both protected and non protected have show that even thought management and research activities to encourage good practices at farm and forest sites, in general no major positive effects have been recorded (Rivard et al., 2000; Hansen, Defries 2007; Tscharntke et al., 2005; Natura 2000; Gontier et al., 2006).

However, the solution of landscape degradation is usually protected areas, which even thought are adequately managed, other activities such as tourism has being increasingly taking place on them that are critical to ecological processes and their performance (Rivard et al., 2000). Hansen, Defries (2007). The argument is that land use surrounding protected areas also have an influence on them like loss of habitants in unprotected will generally have a risk to protected areas; especially as habitat use these areas as corridors (migration effects). More so, different level of water, air pollution and human disturbances of land surrounding protected area will negatively affect them.

Nevertheless, the development of Ecosystem Services (ES) enhances the ecological performance and its decrease reduces them, which can be found in many literatures (Poff, Zimmerman 2010; Urban 2009; MEA 2005). ES are processes and functions of the natural environment providing resources that human benefit from them such as clean water supply, pollination of plants and crops by native species, food provision, regulation of climate and many more (MEA 2005; Fongwa, Gnauck 2009a). These services are spread over different landscape scale depending on natural and anthropogenic conditions in different catchment areas (Patterson 2002). They are often considered as free goods (ESA, 1997), that is taken for granted leading to their decrease in supply due to the social dilemma problems (Fongwa, Gnauck 2009a). Table 1 below contain categories of ES, their types, component and activities that influence them to change.

Table 1. Categories of Ecosystem Services for Estimation

Main Categories of ES	Types of ES	Components for ES	Activities (Balance, Improve and Deficit of ES)
1	2	3	4
Providing	Food, fibre, wood, energy and water	Plant (Tree, grass and crops) and animal species, farmland and Forest-land, water balance, abandonment of pastoral system, Herbs (pharmaceutics), Herbs, Fruits, Vegetables	Irrigation extraction, evapo-transpiration runoff and drainage, grazing and cultivation, tree removal without replanting, animal breeding, Stock feeding, Modification of cultivation practices
Regulating	Water regulation (surface and ground), Control of pest, diseases, climate and air quality	Water quality, filtering water, temperature reduction, pest, diseases, Carbon Sequestration, filtering dust particles air, pollution removal	Pollution by nitrates and pesticides, salinity, acidity and nutrients (P, N and others), production of renewable energy from agro-forestry, greenhouse gas emission and ammonia from agro-forestry, avoidance of emission
Support	Nutrient cycle and crop pollination	Maintenance of soil quality, Nutrients balances, bees population, soil loss, nutrient	Extension of bee, organic farming, ecological farming, feed, fertilizer, burning, energy and acquisition of land, weed, animals pests, release of land, areas of risk of soil erosion, cultivation,

cont. tab. 1

1	2	3	4
Preserving	Maintenance of biological and genetic diversity against uncertainty	Storm mitigation, biological refugia, noise reduction, flood control, richness/abundance of species	Deforestation, land fragmentation, conservation banking, hunting
Cultural	Recreation and spiritual	Aesthetic, monuments sanctuaries, natural parks, secret places, Inspirations, Eco-tourism	Tourist activities, cultural activities, transport, birthplace for various traditional performances, cultural heritage

In addition, many literatures on ecosystem assessment portray ES as an indicator for estimating the ecological performance at the landscape (MEA 2005; Slootweg, van Beukering 2008). Therefore, environmental balancing, ecological performance and development of ES have a positive correlation. For instance reduction of the level of ES will negatively affect the ecological performance due to a deficiency in processes that maintain the environment leading to land degradation. But, an improvement of the level of ES enhances the ecological performance and also the well-being of its community (MEA 2005).

This paper focuses on ES as an indicator for ecological performance and estimates their rate of changes in agricultural and forest landscapes. Two sampling landscape types are considered; protected and none protected agricultural and forest ecosystems in the Kolkwitz community. Data from these two landscape types are combined and modelled to understand the relationship between ES, socio-economic and cultural influences for coupling decision support systems in the modelling framework that can guide strategy development. Figure 1 is a map of Spreewald region showing the location of Kolkwitz within protected area and it surrounding.

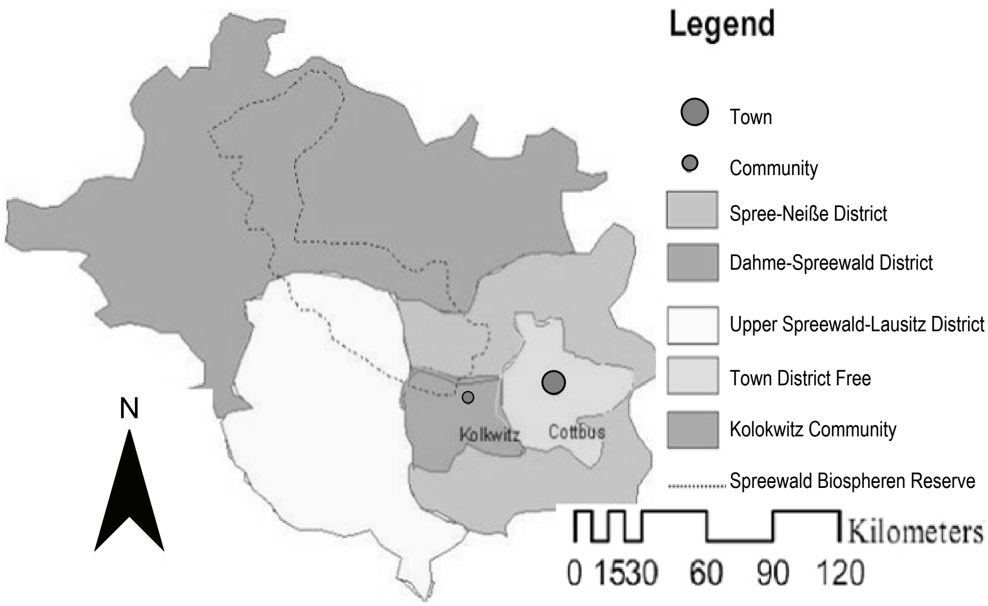

Fig. 1. Map of Kolkwitz Community within the Spreewald Region

The Kolkwitz community is a cultural wet landscape with streams, swamps and marshy land providing room for flora and fauna. The land cover is mostly coniferous forest and broad leaved forest, extensive agricultural lands, swamps with grassland, settlement areas, pastures and moist soils, where green lands form the greatest portion. Agriculture and tourism has growth in the region and the people have preserved their culture making it an attractive community. In this community, there is continuous cover of swamps and reduction of forest land for extension of agricultural activities. Therefore measures are required for sustainable landscape management to ensure the preservation of ES in the activities in this community that are leading to land use changes. This can ensure that the ecological performance is enhanced. The way forward is a modelling framework for estimating changes in ES for decision support systems that can lead to strategy development for balancing them.

In order to estimate changes in ES for strategies to balance them, a flow system with Petri net is structure to measure the stock of activities that lead to deficit or improvement in ES based on the behaviour and actions of different multi-actors on that landscape. A Petri net is a discrete event modelling framework using graphical and mathematically techniques to analysis and formulate decision support system for simulation of strategies for decision support systems based on the nature of studies (Löscher 2009; Wolfgang, Grzegorz 1998; Girault, Valk 2003). The Data collected in the Kolkwitz community were used for running simulations.

However, even though the results show a general weakness in the ecological performance due to a sink in ES in agricultural and forest sites, sustainability schemes are being developed in Spreewald region with different pilot projects. But the observation from sites shows that those schemes need to put in place facilitating mechanisms for changing behaviours and reduce barriers to sustainability practices. The argument is on improving benefits to all stakeholders in the agro-forest communities in Kolkwitz. This argument is based on socio-economic and politic models for encouraging participation through incentives and motivation schemes, and also compromising the economic trade-offs between the different stakeholders in carrying out their economic activities in that community (Fongwa, Gnauck 2009a). Therefore, the model is restructured to couple a strategic framework to foster Community-based Financial Participation (CFP) for preservation of ES. CFP is a financial portfolio platform for investing in ES and benefiting from the returns to the investment based on contributions from stakeholders at the community level (Fongwa, Gnauck 2009b; Fongwa et al., 2009). This can lead to enormous effort in improving the ecological performance at the landscape scale through the incentive that can be generated be the CFP for preservation of ES.

Methodology

A Petri nets modelling frame is designed to analysis ES and activities that influence changes in them as the main variables (see Table 1) for decision support systems. They are the inflow and outflow of the model based on environmental rules of Petri nets realised within multi-actor behaviour patterns (Löscher 2009). The model started with a bottom-up modelling approach to set the rule for determining the phase transition (multi-actors actions) of the Petri net based on events generations, which depends on the net structure and character of data (Wolfgang, Grzegorz 1998). It has been used to model flow system in many fields such as transport, business and industrial processes, genetic, financial and many more. But it has not been used in field of ES, which is also a flow system. Therefore the research under which this paper is written provide the first attempt with it with the first literature in Fongwa, Müller (2010) and seek for formal validation techniques to proof it as suitable for estimating the value of ES in Fongwa et al. (submitted).

A Petri net consists of places (in this modelling framework implying ES units, stock of ES and certification schemes), transitions (implying all the actors for ES, flow and financing ES), and arcs (implying the arrows) that connect them (Löscher 2009; Wolfgang, Grzegorz 1998; Girault, Valk 2003). It Input arcs connects places with transitions, while output arcs start at a transition and end at a place. Places contain tokens (implying different ES such as regulating, providing, supporting, preserving and cultural services); a current state of the modelled system is given by the number (different types of tokens, which are distinguishable by markings) of tokens in each place. Transitions are active components that modelled activities that can occur (the transition fires based on interactions at places), thus changing the state of the system (the marking of the Petri net). Transitions are only allowed to fire (set to work based on behaviour) if they are enabled, which means that all the pre-conditions for their activities must be fulfilled (there are enough tokens available in the input places). When the transition fires, it removes/adds tokens from its input places and adds/removes some at all of its output places. The number of tokens removed/added depends on the cardinality of each arc. The interactive firing of transitions in subsequent markings is called token game (Löscher 2009).

The firing sequence produces the outputs based on the character of data, which depends on the rules for determining the transition sequence that generates the behaviour of the model. Figure 2 below is a graphical presentation of Petri nets modelling system for estimating ES, which shows the various places of the net, the transitions with places that connected them by arcs. From the graph the transition sequence can be determined, that is the arcs that are directed from the actors through the inflow to the stock of ES and from the stock of ES through the outflow to the various actors. This graphic model design is configured and used the structured data collected to simulate estimates of the flow of ES at the sampling units during and after a particular transition event that was recorded in Kolkwitz community. It structure different service units (service consumption, service antagonising, service production and service supplying units) found in places and the various actors (consumers, developers, migrants and suppliers) found in transition that through their interaction influence the flows as indicated with the arrows (arcs).

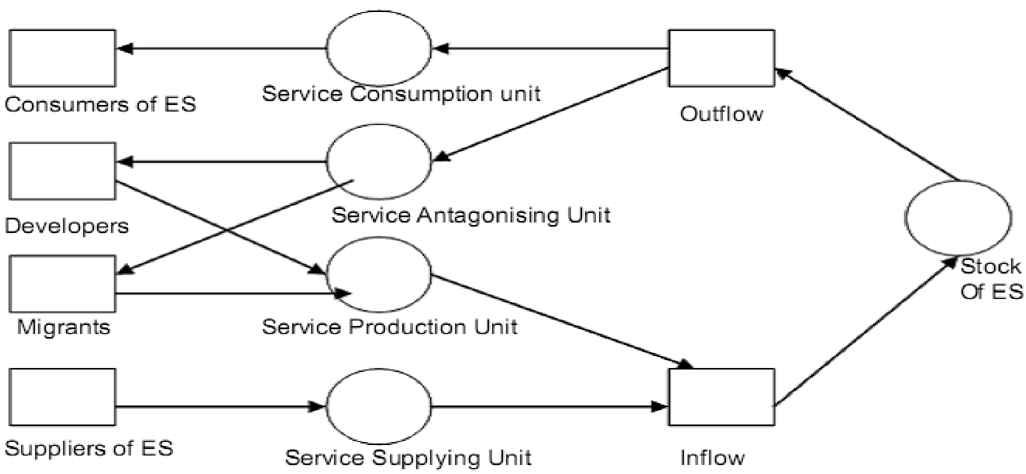

Fig. 2. Petri Nets Modelling for Measuring ES

Input data for estimating ES consisted of a combined field survey through personal observation, interviews and data from administrative authorities as data sources. A cross-site estimation of variables of control mechanisms for ES based on human activities (Table 1) on the protected and none protected sites of Kolkwitz and local people were interviewed on practices carried out in the area to estimate impact on conservation measures. The sampling consisted of 6 sites of about 2km²/site with agricultural and forestry areas selected randomly in the protected and none-protected areas in that community. 60 enterprises directly or indirectly involved with the demand and supply of ES were taken as the typical reference points for data and they were collected as aggregates for tourist and agro-forestry activities. Two main sequences for measurability were considered, each activity identified as a flow of ES is given one token and its sequence depends on whether it demands (inflow) or supplies (outflow) ES. The model simulates the data as variables for statistical analysis to support decision systems and further developed a decision support tool with incentives based on CFP.

Results and Interpretation for Decision Support Systems

The stock of tourist activities for ES recorded 2850 tokens, that is 798 tokens as inflow given 28% and the 2052 tokens as outflow given 72%. Figure 3 below provide a visualisation of results of flow of tourist activities on a histogram, which shows a significant different in the histograms indicating that the ecological performance is negatively affected (deficit in balance). Therefore, the result indicates that for policy measure for environmental balancing of ES, a $\geq$ 22% policy target has to be achieved on reducing negative impacts from tourist activities on ecosystems.

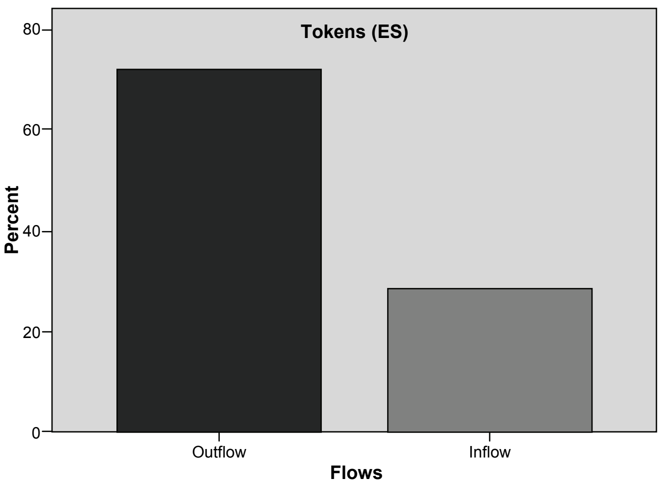

Fig. 3. Flow of Ecosystem services on Tourist Activities

On the other hand, the stock of flow of ES from agro-forestry activities recorded was 335 tokens, that is 134 tokens as inflow given 40% and 201 tokens as outflow given 60%. Figure 4 below provide a visualisation of flow of agro-forest ES that also show an imbalance. Therefore, the result indicates that for policy measure for environmental balancing of ES, a $\geq$ 10% policy target has to be achieved on reducing negative impacts in agro-forestry ecosystems.

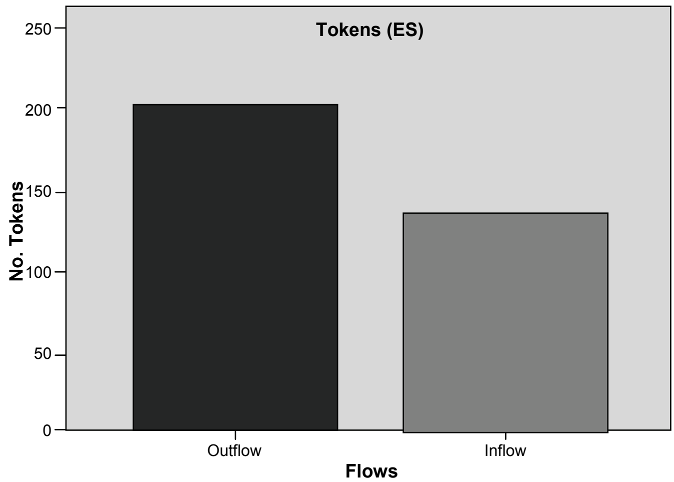

Fig. 4. Flow of Agro-forest Ecosystem Services

Nevertheless, the data might involve substantial amounts of estimation errors, therefore data from administrative reports from this region was also collected and categorised under the demand and supply units for ES to seek their correlation with the collected sampling data using a regression analysis, which show a linear regression with a correlation coefficient of about 0.867.They represent good proxies that the result can be reliable as an indicator for decision support for measures to preserve ES in order to improve the ecological performance in the Kolkwitz landscape.

However, in general the results were further aggregated that show a decrease agro-forest ES and it was surprising that the rate of decrease is greater in the protected sites than the non protected sites. This is due to the influence of the increasing tourist activities in the protected areas giving too much pressure on ES, hence reducing the ecological performance of the landscape. For example, population pressures from tourism leaves behind garbage and pollution associated with their activities, some tourist create their on route for tours leading to soil impaction, erosion and plant damages. Furthermore, invasion of some swamp and marshy lands leads to disruption of ecological life system, especial disturbance of animal diversity. On the other hand, agro-forestry activities caused soil sealing, erosion, deforestation, reduction of grasslands swamps for intensification of agriculture, reduction of biodiversity, pollination of soil and water with nitrates from fertiliser, pesticides and oil for machinery, irrigation activities without water management systems and many more.

However, comparing the observation with other agro-forestry landscapes show that when such landscapes have been granted protection status due to land degradation, they turn to be highly tourist based and if tourist activities are not controlled, it will lead to an exponential rate of landscape degradation (Nowaczek, 2010).

Adaptive Management Strategy for Preserving Ecosystem Services

Sustainability practices for land use management have been introduced in the Spreewald regions such as the certification scheme, which also cover the Kolkwitz community. This scheme has been put in place to enhance the ecological performance of the region by providing sustainability guides to stakeholders to participate in practices to preserve ES. The new pilot project is planned to include the tourism sector in the certification scheme. But the challenge is a motivation approach to encourage an increasing number of stakeholders' participation in the scheme. Figure 5 below shows a diagram of the Spreewald logo, which is a label used to identify an activity or enterprise that is certified under the scheme. The certification is only acquired if the basic sustainability requirements are met for enhancing the ecological performance and preserving ES, which need to be controlled as part of the certification procedure (environmental auditing).

Fig. 5. The Spreewald Logo for Certification Scheme

However, the surveys in the Kolkwitz region show a lack of participation by many enterprises in the system, especially some enterprises that their activities cannot satisfied the certification basic criteria. For instance some enterprises in the region using the old fabrics for carrying intensive cattle rearing that are not ecological friendly and can not meet the basic criteria of the certification scheme, considered the condition as not essential for their business interest, especially as it can directly influence their operation. It is a voluntary scheme to support good practices for enhancing ecological functions and processes to preserve ES. Therefore, there is the need for motivation and incentive schemes for cooperation, to encourage their action to fall within sustainability procedures. The argument is on a CFP framework that can motivate increasing participants in the scheme due to its potential benefits sharing to all stakeholders and reduce the conflicts of interest (Fongwa, Gnauck 2009b; Fongwa et al., 2009). Therefore, the modelling framework is being extended to include all activities that have an impact on ES and the properties of the Petri nets are verified for improving the quality of the modelling procedure, which the net is then being reduced using a top-down modelling strategy (Wolfgang, Grzegorz 1998). After satisfying properties of Petri nets, the net is being extended to couple the existing sustainability scheme (Spreewald logo certification scheme) for preserving ES. The model is then being synchronised at the node of certification schemes (strategy) to involve CFP, which is the arguments here and it is based on socio-economic and political concepts for preserving ES found in Fongwa, Gnauck (2009a). Figure 6 below is a modification of the nets system presented above, which is reduced to have only ES units (the multiple places of ES units are combined) and a transition to have only actors for ES (the multiple transits nodes with actors are combined). The net is being extended to couple another place; certification schemes and a transition of financing ES that are the adaptive strategy of the model. A CPF is implemented in the model by synchronising it within the interface of the place of certification schemes that lies between the two transitions (actors for ES and financing ES). The reason is to include the financial potential of the certification scheme in the CFP framework that can be carryout with actors for preserving ES. This can provide a strong incentive and motivation scheme for the preservation of the demanded ES at the landscape scale through participation in the logo schemes. Especially when people were asked about the risk from legal consequences for their activities or uncertainty from being excluded from community development opportunities, if there is no cooperation of the different stakeholder with different interests, then CPF was acknowledged as a potential. This is because of free rider effect and willingness to pay for ecological damage to society is usually a problem (Bell et al., 2003; Gatto, De Leo 2000; Fongwa, Gnauck 2009a).

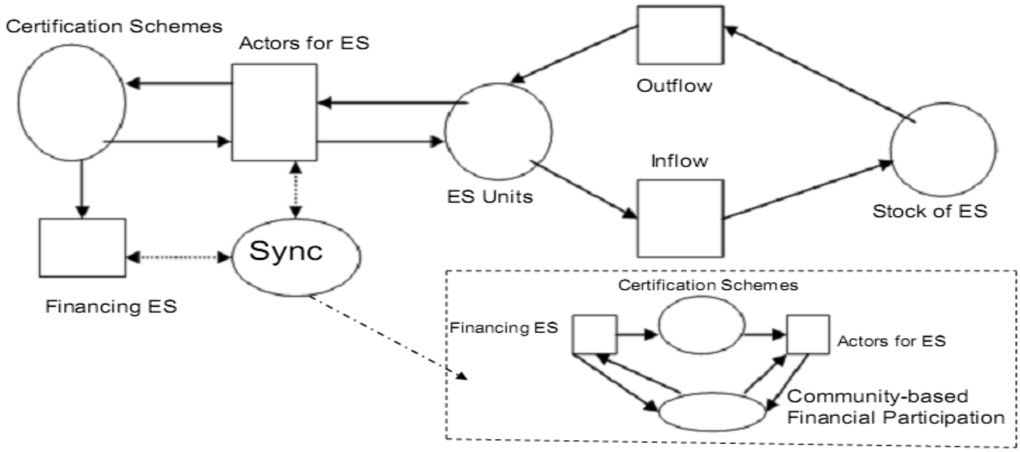

Fig. 6. A Modification of the Petri Net to include Strategies

Community-based financial participation is a financial plan for investing in ES that can involve all actors carrying out activities in an ecosystem community (Fongwa, Gnauck 2009b; Fongwa et al., 2009). Figure 7 below shows a framework of CPF for preserving ES. It represents the actors for ES; private investors, local governments, institutions, households and businesses, and also financial institutions can play a dual role by contributing directly or providing credits in the case of high profitable investments. It can be strategic because those who do not contribution to the scheme will know that they will be excluded from the benefits of ES at the landscape and only benefit in their functional services, which they cannot be excluded. Therefore, everybody in the ecosystem community can be encouraged to participate in the preservation of ES, especially through the certification scheme.

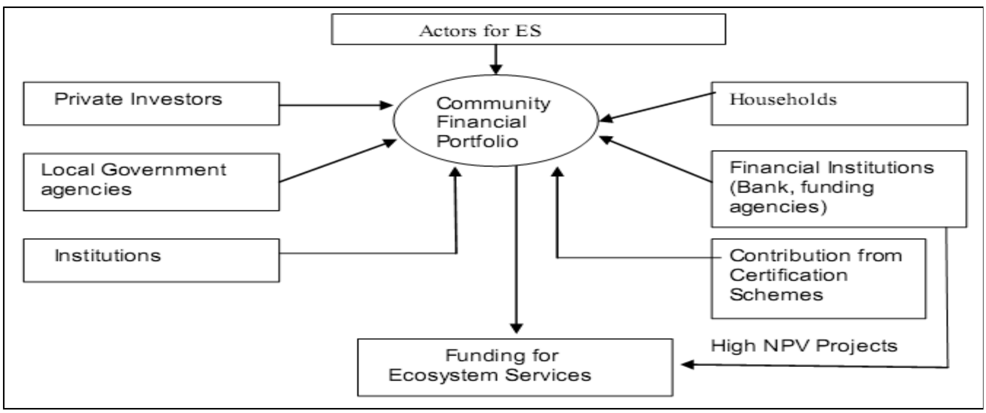

Fig. 7. Community-based Financial Participation for ES
Modified from Fongwa, Gnauck 2009b

Discussion and Conclusion

The trends in the ecological performance on the landscape from different assessments literatures show reduction of ES (MEA 2005; Urban 2009; Gontier et al., 2006; Grimm et al., 2008). However, the vision of decision making procedure on landscape management is to provide support systems that can encourage an increasing recognition of the value of nature to preserve ES and at the same time foster human well being (MEA 2005). When individuals, institutions, especially local government agencies appreciate natural systems as vital assets and the central roles they play in supporting human life systems, then multi-stakeholders participation for preserving them will be encouraged. But the challenge is that institutional capacity for preserving ES are poorly engaged in decision support systems, especially incorporating tangible and intangibles ES and their relationship to different stakeholders for institutional capacity building. This is because having the right institutions can create incentives for widely shared values for preserving ES. Incentives schemes can provide an important source of support for preserving nature, which can change behaviour and gear activities that are being carried out by different actors on the landscape scale toward conservation practices. We estimate the rate of ecological performance at landscape for development of decision support systems using a Petri net modelling framework. We defined service units of flow of ES on a landscape scale based on multi-actor interaction and collect data from Kolkwitz community to run the simulation. The results showing the need for more cooperation with stakeholders in the landscape to enhance ES that we synchronised a CFP framework in the modelling for decision support system for encouraging multi-actors to participate in sustainability schemes in the region that encourage the preservation of ES.

Nevertheless our modelling approach is the first attempt using Petri net for estimating ES at the landscape and developing a decision support tool, so there may be knowledge gaps that need further improvement for reliable results. But, nevertheless the simulation results were correlated with existing data that provide good proxies indicating they may be a reliable tool for decision support system for preserving ES. Therefore, this paper can be use to inform decision makers on landscape management for decision support procedures that determine typical impact units for estimation of changes on landscape and how ecological parameters can be enhance based stakeholders behaviour patterns. Also, it show that financial portfolio for funding projects to enhance ES on the landscape can be realised with stakeholder through financial participation at the community-based level, which can reduce local government and funding agency level of involvement in financing developmental projects at the landscape scale. These arguments can provide guidelines for estimating decision support systems for improving the ecological performance and development of sustainable management strategy, policies and programs to fight land degradation. Therefore the support of scientists and experts are required for examining this potential for recommendation to decision makers on procedures for developing decision system for programs and projects at the policy level.

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References

Bauer, S., Stringer, L.C. 2009. The Role of Science in the Global Governance of Desertification. Journal of Environment and Development 18 (3), p. 248–267.

Bell, K., Huppert, D., Johnson, R. 2003. Willingness to Pay for Local Coho Salmon Enhancement in Coastal Community. Marine Resource Economics 18 (1), p. 15–31.

Chamberlain, D., Fuller, R., Bunce, R., Duckworth, J., Shrubb, M. 2000. Change in the Abundance of Farmland Birds in Relation to the Timing of Agricultural Intensification in England and Wales. Journal of Applied Ecology 37, p. 771–788.

ESA 1997. Ecosystem Services: Issues in Ecology. Published by Ecological Society of America (ESA) 2.

Fongwa, E., Gnauck, A. 2009a. Value creation from Ecosystem Services for business development. In: Modeling and Simulation of Ecosystems: Kölpinsee Workshop 2008. Gnauck, A. (ed.). Shaker Verlag, p. 43–56.

Fongwa, E., Gnauck, A. 2009b. Community-based Financial Participation for Developing Ecosystem Services at the Landscape Scale. In: European Landscapes in Transformation: Challenges for landscape ecology and management: European IALE Conference 2009, 70 years of landscape ecology in Europe. Breuste, J., Kozova‘, M. and Finka, M. (eds.). University of Salzburg (Austria), p. 413–416.

Fongwa, E., Oana N., Mircea D., Gnauck A., Wagner G. 2009. Agent-based Discrete Event Simulation of a Community-based Financial Portfolio for Business Development. In: 20th Symposium Simulation Techniques: ASIM 2009. Gnauck, A., Luther, B. (eds.). Shaker Verlag, Extend Abstracts, p. 144–147, full paper in CD, p. 294–303.

Fongwa, E., Müller, F. (Authors), Costanza R. (Topic Editor) 2010. „Modelling system for estimating the value of ecosystem services." In: Encyclopedia of Earth. Eds. Cutler J. Cleveland (Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment). [First published in the Encyclopedia of Earth December 31, 1969; Last revised June 2, 2010; Retrieved July 22,2010].

http://www.eoearth.org/article/Modelling_system_for_estimating_the_value_of_ecosystem_services.

Fongwa, E. Gnauck, A., Müller, F. (submitted). New Approach for Estimating the Value of Ecosystem Services: Petri net model building and validation. Submitted for Special Issue of Journal of Ecological Indicators (Salzau 2010 papers).

Gatto, M., De Leo, G.A. 2000. Pricing Biodiversity and Ecosystem services: The never- ending story. Bioscience 50, p. 347–355.

Girault, C. and Valk, R. 2003. Petri Nets for Systems Engineering: A guide to modeling, verification, and applications. Springer-Verlag.

Gontier, M., Balfors B. and Mörtberg U. 2006. Biodiversity in Environmental Assessment: Current practice and tools for prediction. Environmental Impact Assessment Review 26: 268–286.

Grimm, N.B., Faeth, S.H., Redmann, C.L., Wu, J., Bai, X., Briggs, J., Golubiewski, N.E. 2008. Global Change and Ecology of Cities. Science 319, p. 756–760.

Hansen, A.J., Defries R., 2007. Ecological Mechanisms Linking Protected Areas to Surrounding. Ecological Application 17 (4), p. 974–988.

Kleijn, D., Sutherland, W.J. 2003. How Effective are European Agro-Environment Schemes in Conserving and Promoting Biodiversity. Journal of Applied Ecology 40, p. 947–969.

Löscher, T. 2009. Optimisation of Scheduling Problems Based on Timed Petri Nets. ARGESIM Report. ARGESIM/ASIM.

MEA 2005. Overview of the Millennium Ecosystem Assessment. Millennium Ecosystem Assessment (MEA), Island Press.

Natura 2000. A European Network of Protected Sites: Established in compliance with EU-Directives 79/409/EEC (bird and habitat directives), European Union(EU).

Nowaczek, A. 2010. Ecotourism: Principles and Practices. Annals of Tourism Research 37 (1), p. 270–271.

Patterson, M. 2002. Ecological Production-based Pricing of Biosphere Processes. Ecological Economics 41, p. 457–478.

Poff, N.L., Zimmerman, J.K.H. 2010. Ecological Responses to Altered Flow Regimes: A literature review to inform science and management of environmental flows. Fresh water Biology 55 (1), p. 194–205.

Rivard, D.H., Poittevin, J., Plasse, D., Carleton, M., Currie, D.J. 2000. Changing Species Richness and Composition in Canadian National Parks. Conservation Biology 14 (4), p. 1099–1109.

Slootweg, R., van Beukering, P. 2008. Valuation of Ecosystem Services and Strategic Environmental Assessment, Lessons from Influential Cases. Netherlands Commission for Environmental Assessment, Utrecht.

Tscharntke, T., Klein, A.M., Kruess, A., Steffan-Dewenter, I., Thies, C. 2005. Landscape Prespective on Agricultural Intensification and Biodiversity: Ecosystem Services Management. Ecology Letter 8, p. 857–874.

Urban, E. 2009. The Rural Landscape of Europe: How man has shaped European Nature. Swedish Research Council Formas.

Wolfgang, R., Grzegorz, R. (eds). 1998. Basic Models: Advances in Petri Nets. Lecture on Petri Nets 1, Springer Verlag, Lectures Notes in Computer Science 1491.