Small-scale Forestry (2012) 11:285–300
DOI 10.1007/s11842-011-9184-9

RESEARCH PAPER

Smallholder Agroforestry in Rwanda: A SWOT-AHP Analysis

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Accepted: 28 September 2011 / Published online: 15 October 2011

Abstract The perception of Rwandan government officials, NGOs, and extension specialists about smallholder agroforestry adoption as a strategy for smallholder farmers in Rwanda was investigated using a strengths, weaknesses, opportunities, and threats analysis framework combined with the analytical hierarchy process. Results indicate that smallholder agroforestry is viewed positively as a suitable strategy for Rwandan smallholder farmers. The most important positive features were the potential for increased agricultural output from agroforestry and a favorable policy environment in Rwanda supporting sustainable agriculture. Results also indicate that there needs to be better coordination of various efforts to promote agroforestry and stronger extension services for smallholder farmers. Carbon offset markets and other environmental service markets were seen as a potential opportunity for smallholder agroforestry. However, the results also indicate that there is substantial uncertainty and skepticism concerning how such markets would benefit smallholder farmers who adopted agroforestry.

Keywords Agroforestry · Smallholder farmers · Rwanda · SWOT-AHP

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Introduction

Agroforestry, the inclusion of trees with food crops or pasture, offers great potential in Rwanda as a way to provide sustainable income to farmers, sequester carbon, produce bioenergy, and enhance other environmental services such as biodiversity, water quality enhancement, and soil fertility improvements (Balasubramanian and Egli 1986; Garrity et al. 2010; Jose 2009; König 1992; Roose and Ndayizigiye 1997). As a result, there has been significant effort by the government of Rwanda, the World Agroforestry Center, and several donor agencies to develop beneficial agroforestry systems and promote their adoption by smallholder farmers—who make up the majority of the rural farming population in Rwanda. However, the success of smallholder agroforestry depends on several factors such as the impact of agroforestry on food production and income, perceived and actual risk of agroforestry, access to markets, and farmer familiarity with agroforestry. Knowledge and perception of these factors can enhance the development and adoption of agroforestry systems. This study uses the AHP (analytical hierarchy process) combined with SWOT (strengths, weaknesses, opportunities, and threats) analysis to determine important factors impacting smallholder agroforestry in Rwanda.

Rwanda has a population of approximately 11 million people living on just 26,000 square km of land making it one of the most densely populated countries in Africa. As a result, Rwanda has only about 0.65 hectares of suitable farmland per household (Rutunga et al. 2007). Approximately 95% of the population is engaged in some form of agriculture, mostly smallholder subsistence that is characterized by low input use. Because the vast majority of Rwandans are dependent on agriculture for sustenance and income, agricultural development is an important component of the government's strategy to reduce poverty. Specifically, Rwanda's Economic Development and Poverty Reduction Strategy (EDPRS), the government's strategy for economic development over the next several years, has a goal to sustain an annual growth rate in agricultural GDP of 7% (Ministry of Agriculture and Animal Resources 2009).

Rwanda's climate is tropical with sufficient rainfall throughout most of the country for rain fed agriculture which occurs on 95% of the cultivated land (Kannan et al. 2010). However, crop production often suffers during the dry season and during droughts that occur periodically. In addition smallholder farmers cultivate hillsides with slopes up to 55% (Ministry of Agriculture and Animal Resources 2009). As a result, almost 50% of the agricultural land in Rwanda shows signs of soil erosion indicating a reduction in the capacity of the land to produce food and fiber. The Rwandan Ministry of Agriculture and Animal Resources (2009) reported that soil erosion causes a total soil loss of about 15 million metric tons per year, equivalent to losing the capacity to feed 40,000 people annually. Rwanda also has one of the most severe nutrient depletion rates in Africa with an average of −54 kg N, −20 kg P_2O_5, and −56 kg K_2O per hectare per year (Stoorvogel and Smaling 1990). Henao and Baanante (1999) reported negative NPK soil balances estimated at −123.8 NPK kg per hectare during the years 1996–1999. As a result, the documented yields of legumes and beans have been declining over recent years (International Institute for Sustainable Development 2005).

Agroforestry can help smallholder farmers confront these challenges. For instance, agroforestry systems can prevent soil erosion and replenish soil nutrients, such as nitrogen, phosphorus, calcium and magnesium and thus aid in increasing agricultural output (König 1992; Roose and Ndayizigiye 1997; World Agroforestry Center 2010). For example, research conducted in several sub-Saharan countries in Africa demonstrate that the inclusion of certain trees into agricultural systems can substantially increase the output of annual crops by adding fixed nitrogen to the soil, cycling other nutrients, and providing greater organic content to the soil (Garrity et al. 2010; Quinion et al. 2010). Research done at the Rubona Agricultural Research station in Rwanda, showed that the combination of agroforestry leaf biomass from *Calliandra calothyrsus*, *Tithonia diversifolia* and *Tephrosia vogelii* and a moderate dose of phosphorus (25 kg per ha) increased maize grain yields and phosphorus absorption in highly degraded and acidic soils (Mukuralinda et al. 2010).

In addition to the current agricultural challenges facing Rwanda, climate change is projected to negatively impact food production by increasing climate variability and extremes (Battisti and Naylor 2009; Working Group on Climate Change and Development 2006). However, agroforestry has the potential to be an effective strategy to help smallholder farmers to adapt to climate change. Agroforestry offers several advantages over other agricultural systems in terms of helping smallholder farmers cope with the expected changes. Agroforestry helps diversify production to a wider range of agricultural and forest products and thus, buffers against the increased climatic variability that is expected to result from climate change. Agroforestry can also improve agricultural output in both dry and wet periods by increasing soil porosity, reducing runoff, and utilizing deep rooted trees during periods of drought and increasing evapotranspiration rates, and soil aeration during wet periods (Verchot et al. 2007). Reducing the vulnerability of smallholder farmers to increased climatic change should be a substantial component for alleviating rural poverty as farmers are often forced to sell off valuable assets (i.e. livestock) that represent a significant component of their wealth during periods of drought or flood when subsistence food production drops.

Agroforestry also provides a means for smallholder farmers to diversify their farms through the production of firewood, building material, fruits, and other tree products. The majority of smallholder farmers in Rwanda use wood or wood-based charcoal as their main energy source. Yet deforestation and poor management of wood plantations threatens this important natural resource. Rwanda has insufficient forest resources to meet the growing demand for timber products and woody bioenergy (Rutunga et al. 2007). Agroforestry could play a constructive role in alleviating this threat by providing smallholder farmers with access to multipurpose trees that can produce not only firewood or charcoal but timber, poles, and other wood products (Ndayambaje 2005; Rutunga et al. 2007). The production of these products could also relieve pressure on protected forests by reducing the incentive of the local population to enter protected areas to gather these resources (Bhagwat et al. 2008). Sub-Saharan Africa has lost approximately 3.4 million hectares of forests per year over the last 10 years (United Nations 2010). Since independence Rwanda has lost a substantial amount of its forested areas. For example, Gishwati

Forest Reserve has been reduced to just 7 km^2 from about 280 km^2 and Mukura Forest Reserve has been reduced to around 8 km^2 from 50 km^2 over a period of a few decades (Weber et al. 2005).

In addition to the above benefits to the sustenance needs of smallholder farmers, agroforestry can provide and enhance several environmental services with regional and global importance (Jose 2009). Forested systems including agroforestry can provide substantial carbon offsets relative to treeless agricultural systems (Nsabimana 2009; Nair et al. 2009). For example, research has shown that agroforestry can sequester 1.5 to 3.5 Mg carbon per hectare per year (Montagnini and Nair 2004). Agroforestry can also protect biodiversity by providing habitat for species that can tolerate a certain amount of disturbance, reducing the pressure to convert natural ecosystems, and linking natural habitat fragments (Bhagwat et al. 2008; McNeely and Schroth 2006). Finally, agroforestry can enhance water quality and quantity by decreasing soil erosion and increasing water filtration (Jose 2009; Stainback and Masozera 2010). These environmental services can potentially provide income to smallholder farmers through environmental service markets (Food and Agriculture Organization of the United Nations 2007). For example, carbon offsets from agroforestry can be sold in international carbon markets and utilities and tea estates can pay upstream smallholders for enhancement of water quality (Stainback and Masozera 2010).

Numerous studies surveying smallholder farmers in the tropics have identified preferences, farmer resource endowments, financial incentives, biophysical factors, and uncertainty and risk as important factors influencing adoption rates (Caveness and Kurtz 1993; Franzel 1999; Mercer 2004; Pattanayak et al. 2003). Land tenure tends to be critical in agroforestry adoption due to the longer period of time it takes to receive some of the benefits (Clay et al. 1998; Mercer 2004). How various factors specifically impact smallholder agroforestry adoption can vary between countries or regions due to differing economic, social, and institutional characteristics (Gershon et al. 1985). Information regarding the specific issues concerning agroforestry in Rwanda can provide valuable insights to policymakers and others in designing and implementing more effective agroforestry policies and extension services.

Methodology

One of the advantages of using a focus group setting is that the open-ended nature of the discussion allows participants to identify issues unknown or considered unimportant by the researcher. This is particularly important in issues such as smallholder agroforestry that involve complex interactions between social, institutional, and economic factors. SWOT is a technique that allows a focus group to identify the strengths, weaknesses, opportunities, and threats in adopting a particular strategy—in this case smallholder agroforestry in Rwanda. Strengths and weaknesses are factors that are internal (i.e., factors that are a direct result of adopting the strategy) while opportunities and threats are external (e.g., market conditions, the policy environment, etc.) to the situation. SWOT has been used in a variety of strategic planning contexts (Houben et al. 1999; Mollenhorst and de Boer 2004;

Nair and Prasad 2004). However, alone it does not provide a means to estimate the relative importance of the various SWOT factors either within a category or among categories. For instance, usually several factors under each category of strengths, weaknesses, opportunities, and threats are identified. A traditional SWOT analysis identifies these factors but does not give a relative priority of the factors in each category (i.e., factors within the category of strengths) or allow estimation of the relative priority of the different categories (i.e., strengths versus weaknesses). The AHP technique developed by Saaty (1977) allows estimation of the relative priorities for each factor and category. Focus group participants make comparisons between factors within each category and between each category using a predetermined scale. Relative priorities of factors and categories are estimated using the eigenvalue technique (Saaty 1977). A more detailed explanation of the eigenvalue technique is given in the "Appendix".

A one-day workshop consisting of agroforestry experts was held in Kigali, Rwanda in November 2010 to conduct the SWOT-AHP analysis. Participants included scientists working on agroforestry in Rwanda, agricultural extension personnel involved in assisting smallholder farmers in adopting agroforestry, NGO representatives interested in promoting agroforestry, and representatives of the Rwandan government with the knowledge of agroforestry. The participants represented a diverse set of perspectives on agroforestry. The vast majority of the participants were Rwandan and had worked on Rwandan agriculture for a significant amount of time. All had knowledge of at least one important aspect of agroforestry in Rwanda. Some had substantial scientific knowledge of Rwandan agroforestry, some had knowledge of the challenges and needs of smallholder farmers in the country, while others were knowledgeable about some of the benefits and obstacles concerning agroforestry from a macro or government perspective. Many of the participants worked extensively with Rwandan smallholder farmers and some came from families of smallholder farmers. The objective in choosing the participants in the focus group was to assemble expertise in smallholder agriculture, the technical aspects of agroforestry, and the macroeconomic effects and concerns of widespread agroforestry adoption in Rwanda. In this study we chose to focus on government officials, NGO representatives and people working in agricultural extension in Rwanda. The focus groups were designed to get the perspectives of policymakers and people who will implement policies designed to encourage agroforestry in Rwanda. We did not include smallholder farmers in the focus groups. However, previous studies have looked at the preferences for and adoption of agroforestry by smallholder farmers in the tropics through various survey techniques and economic modeling. (Franzel 1999; Mercer 2004; Mercer and Snook 2004; Pattanayak et al. 2003). Few studies have looked the perspective of people designing and implementing agroforestry policy.

The focus group was first presented with a short presentation explaining the purpose of the workshop. Next they were presented with a brief overview of smallholder farmer agroforestry and why there is an interest among the Rwandan government, NGO's, and others in promoting agroforestry adoption in Rwanda. Finally, the methodology and specific issue or question to be addressed by the SWOT-AHP session was explained. The first part of the workshop consisted of a brainstorming session to identify factors in each SWOT category that are important to the adoption of agroforestry by Rwandan smallholder farmers. First, all factors identified by individual members of the focus group were listed. Next, similar factors that expressed the same broad issue where combined into one descriptive factor. This was conducted as a group exercise involving all participants. Next the top three factors in each SWOT category were chosen by group consensus. Thus, the three most important factors in each SWOT category were identified by the focus group at the end of this session.

After a break, a second session was held. In the second session, the participants were divided into two groups consisting of 4 or 5 individuals—one consisting of researchers or others with a more technical or scientific understanding of agroforestry and another with more experience and understanding of the social, extension, and policy aspects of agroforestry adoption in Rwanda. The two groups were then tasked with making pairwise comparisons between each of the three factors in each SWOT category (see Fig. 1). After these comparisons, the factor in each category with the highest priority was brought forward to be compared in a pairwise manner with the highest priority factor in the other SWOT categories. After the first rounds of comparisons were made they were checked for consistency with one another. Inconsistency occurs when multiple comparisons involving the same factor do not reflect the same priority for that factor (see the "Appendix" for a more quantitative explanation). Due to limitations in human judgment and differing viewpoints among group participants absolute consistency is not expected (Margles et al. 2010). After the one-day workshop, a smaller group of participants made minor adjustments to some tradeoffs to ensure that consistency was kept within acceptable levels (less than 10%). The software Expert Choice version 11.5 was used to estimate priorities (Expert Choice Inc. 2010).

Results and Discussion

The SWOT factors of smallholder agroforestry in Rwanda are shown in Table 1. The group, consisting of extension and research representatives, identified four to six factors in each SWOT category (strengths, weaknesses, etc.) that they felt represented the possible benefits and challenges of increasing adoption of smallholder agroforestry in Rwanda. Each category was analyzed and discussed

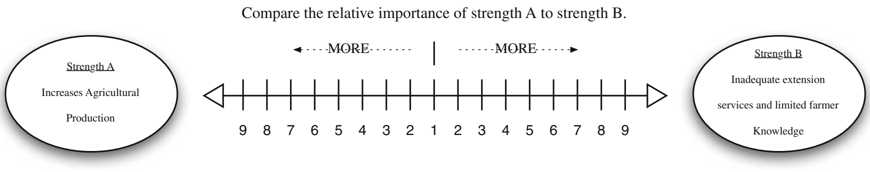

Fig. 1 An example of a pairwise comparison of strength factors. The respondent is asked to assign a value of 1–9 to one of the factors to indicate the relative importance of that factor over the other. A response of 1 would indicate that the factors are equally important. A response of 9 would indicate extreme importance of that factor relative to the one it is being compared with

and the group chose the most important factors in each. Strengths and opportunities represent the positive aspects of smallholder agroforestry. The group perceived increased agricultural production in terms of food and other outputs, such as firewood and fodder for livestock, as critical. Many smallholder farmers in Rwanda are subsistence farmers and farm small plots of land, so any agricultural technique that could increase the productivity of farmer labor was seen as important. Increased provision of environmental services was also seen as important. As stated earlier, loss of soil productivity and erosion are common problems faced by smallholder farmers in Rwanda. In addition, the group strongly felt that agroforestry could both contribute and take advantage of a stable and favorable political environment at the local and national level in Rwanda. For instance, land tenure is increasingly secure and the government is making sustainable agriculture a priority. Finally, carbon market opportunities such as the UN-REDD program and voluntary carbon markets were seen as potential ways to diversify and increase the income of smallholder farmers through agroforestry. Carbon markets and other environmental service markets could potentially provide a means to increase cash income for smallholder farmers that could be used to smooth out lean years and/or invest in increased agricultural output (i.e., buying fertilizer or investing in small scale irrigation).

Table 1 Factors identified in each SWOT category by the whole group (both researchers and extension). The group identified the most important three (shown in bold) in each category to be used later in pairwise comparisons. Factors are listed in alphabetical order

Strengths	Weaknesses
Farmers are receptive and hard workers	High investment costs and access to tree seeds or seedlings
Increased accessibility to firewood and other uses (i.e. sticks for beans, fodder for livestock)	**Inadequate extension services and limited farmer knowledge**
Increased agricultural production	**Lack of coordination of agroforestry interventions**
Increased provision of environmental services	**Long time to get benefits**
	Small land size and competition with annual crops
Opportunities	Threats
Existence of tree seed center and agroforestry research results	Change of government policies
Existing community based forestry projects, community based organizations and partners	**Climate change and variability**
Favorable political environment	**Lack of alternative sources of energy**
Global carbon market (and other enivoronmental service markets)	**Population growth**
Willingness of international organizations to fund farmer related activities	Too high expectations among smallholder farmers for short term benefits
	Unpredictability of carbon markets and lack of government legal and institutional framework for carbon markets

Weaknesses and threats are the negative aspects of smallholder agroforestry adoption in Rwanda. Inadequate extension services and limited farmer knowledge of agroforestry options were seen as major weaknesses of smallholder agroforestry in Rwanda. The group felt that smallholder farmers would benefit from more knowledge about how to take advantage of the benefits from agroforestry. There are government agencies and extension services available to smallholder farmers and a myriad of NGOs that work in various ways that impact smallholder agroforestry. However, there was a general sense among the participants that there often was not much coordination or collaboration between different organizations that have an interest in and that could impact agroforestry adoption. Finally, a weakness identified by the group was the longer time to reap the benefits from growing trees. Many smallholder farmers in Rwanda are frequently faced with immediate sustenance needs, and therefore have a very high discount rate that would value immediate benefits over those that may be years away. Therefore, it was seen as important to have policy and extension services that helped farmers reap any potential short-term benefits from agroforestry.

Climate change was seen as an important threat to smallholder agroforestry. Most climate change models predict Sub-Saharan Africa, including Rwanda, to be substantially impacted in a negative way from future climate change (Battisti and Naylor 2009; IPCC 2007). As stated previously climate change is predicted to make agriculture, including agroforestry, more difficult by reducing production and causing greater climatic variation. The group also viewed population growth as a major obstacle to smallholder agroforestry. Rwanda is the most densely populated country in the Africa and many smallholder farmers are already farming on a hectare or less. The population of Rwanda is predicted to grow substantially over the next several decades and encouraging smallholder farmers to devote some portion of their land to trees will become more difficult if land sizes continue to decrease. Finally, the lack of alternative energy sources was viewed as a potential threat. Charcoal is the main source of energy for cooking in much of Rwanda. Agroforestry was viewed as playing a role in addressing the demand for charcoal. However, many in the group felt that the lack of alternative sources of energy could potentially put great pressure on all forested systems, including agroforestry, and make it more difficult to produce other important benefits of agroforestry (i.e., food, fodder, carbon offsets or other environmental services).

In Table 2 results are presented as local and global priority scores. Local priority scores are the relative priorities of the factors in each SWOT category when compared with each other. Within each category they sum to one. The columns of global priority scores represent the relative priority scores of each category, determined by making comparisons between the factors in each category with the highest priority. The numbers in bold represent the priority of each SWOT category relative to the others. They also sum to one. The other numbers in the global priorities columns represent the global priority of each individual factor determined by multiplying its local priority by the priority of its category. Graphical representations of global priority scores is shown in Figs. 2 and 3.

The results indicate that both the researchers and extension group view the positive factors (strengths and opportunities) of smallholder agroforestry adoption

Table 2 SWOT factors and their priority scores

SWOT categories and factors	Local Priority scores of factors		Global priority scores	
	Researchers	Extension	Researchers	Extension
Strengths			**0.115**	**0.461**
S1: Increases agricultural production	0.614	0.655	0.071	0.302
S2: Increased accessibility to firewood and other uses (i.e. sticks for beans, fodder for livestock)	0.117	0.095	0.013	0.044
S3: Increased provision of environmental services	0.268	0.25	0.031	0.115
Weaknesses			**0.271**	**0.236**
W1: Inadequate extension services and limited farmer Knowledge	0.263	0.691	0.071	0.163
W2: Long time to get benefits	0.079	0.218	0.021	0.051
W3: Lack of coordination of agroforestry interventions	0.659	0.091	0.179	0.021
Opportunities			**0.562**	**0.135**
O1: Favorable political environment	0.705	0.644	0.396	0.087
O2: Global carbon market (and other environmental service markets)	0.084	0.085	0.047	0.011
O3: Existing community based forestry projects, community based organizations and partners	0.211	0.271	0.119	0.037
Threats			**0.052**	**0.168**
T1: Climate change and variability	0.136	0.333	0.007	0.056
T2: Population growth	0.625	0.570	0.033	0.096
T3: Lack of alternative sources of energy	0.238	0.097	0.012	0.016

Numbers in bold are priority scores for the SWOT category

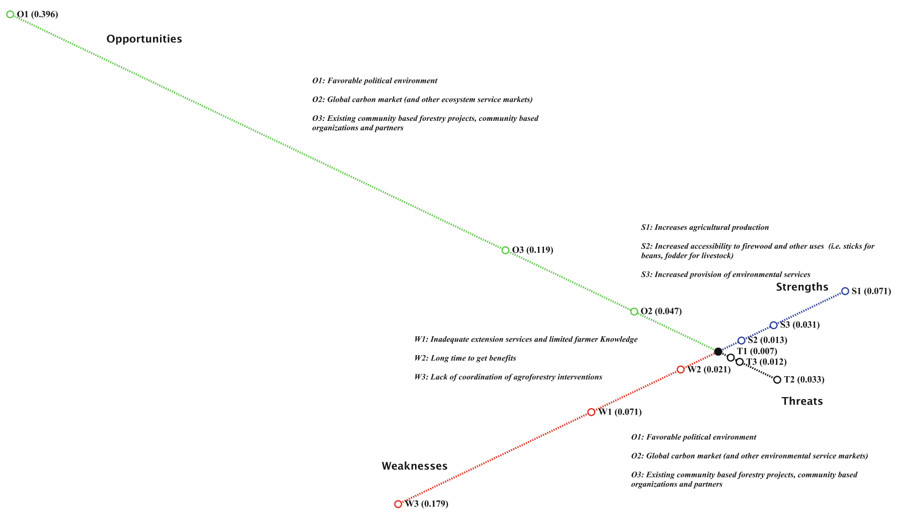

Fig. 2 Global priority scores of SWOT factors for researchers

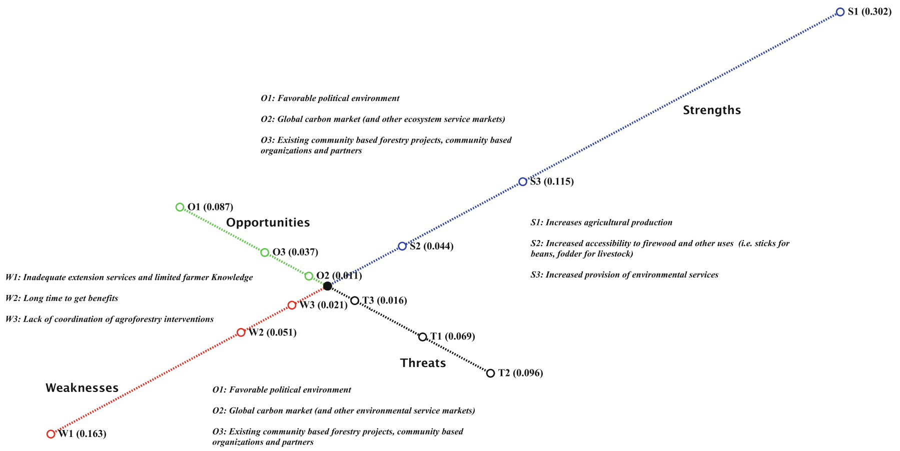

Fig. 3 Global priority scores of SWOT factors for extension

as more important than the negative factors (weaknesses and threats). The combined positive priority value (strengths and opportunities) given by researchers was 68% (0.677) relative to the combined negative priority value (weaknesses and threats) of 32% (0.323). Likewise extension gave a combined priority of strengths and opportunities a value of 60% (0.596) relative to weaknesses and threats. This indicates that both groups, researchers and extension, view agroforestry as a suitable strategy for smallholder farmers and as something that government, NGOs, and others should support. Researchers viewed a favorable political environment as a very important opportunity. As can be seen from Fig. 2, this factor is primarily responsible for the group's large priority of the opportunities category. The discussion indicated that this was related to how important this group felt that local and national government support was to agroforestry and agricultural development generally. Extension and technical advice require support from the government. In addition, because of the investment in time needed for agroforestry, secure property rights are essential for it to be a suitable strategy for smallholder farmers. The government of Rwanda has reformed its land laws, giving every farmer land title, and is making sustainable agricultural development a high priority creating a more conducive policy environment for farmers to adopt sustainable agricultural practices, including agroforestry. The group felt it was crucial to utilize this opportunity to advance agroforestry and its benefits. The extension group gave a very high priority to increased agricultural production that can result from agroforestry. This likely reflects their knowledge of the potential agricultural production increases that agroforestry affords and of the importance of enhanced income generation to rural poverty alleviation. Increased income can also indirectly lead to further production increases as farmers can invest in other agricultural inputs such as fertilizer or improved seeds (Polak 2008). The extension group also gave increased provision of environmental services a high priority. The discussion indicated that this was at least partly due to the interrelatedness of environmental services such as erosion prevention, nitrogen fixation and other soil enhancements, and agricultural production.

Researchers indicated that the lack of coordination of agroforestry interventions was the most important weakness while extension indicated that inadequate extension services and limited knowledge of farmers was the most important factor in the weakness category. In the discussion, the extension group indicated that they felt that agroforestry provides substantial benefits to smallholder farmers and the environment but that many smallholder farmers lacked the knowledge of both agroforestry and the benefits it provides. Even though growing trees on farmland has traditionally been practiced in Rwanda, the extension group indicated that many smallholder farmers lacked knowledge of many modern agroforestry techniques. Researchers perceived that even though there are many government agencies and NGOs working in agroforestry, their efforts were disconnected from each other with no coordination or coherent policy specific to agroforestry. Neither group ranked the longer time it takes to get some benefits of agroforestry as the highest factor, though extension gave it a higher ranking than researchers. During the discussion, it was indicated that agroforestry can provide benefits—in terms of direct products and indirect benefits to soil productivity in a relatively short time frame and that these benefits could, at least partially, compensate for some of the other benefits (i.e. timber, charcoal, fruit) that may take a longer time. Both groups felt that population growth was the most important threat to smallholder agroforestry adoption in Rwanda as this will lead to further reduction in farm sizes. Further reductions in landholding size due to population growth was seen as potentially thwarting the viability of agroforestry as smaller plot sizes have less flexibility for diversified production such as agroforestry. Finally, The global carbon market and other environmental service markets did not rank as highly as the other opportunities for smallholder agroforestry. This result likely reflects that carbon payments are new and still seen as a hypothetical future opportunity by many.

Conclusions

The results clearly indicate that both groups, researchers and extension, view agroforestry as a suitable strategy for smallholder farmers in Rwanda. As stated previously, increased agricultural production was the strongest strength factor and a favorable political environment was viewed as the most important opportunity. Both local and national levels of government in Rwanda are stressing increased agricultural production and rural development generally. This is not the case in all developing countries and has not always been the case in Rwanda. Without favorable support from the government, it is difficult to promote a strategy such as agroforestry on a large scale. Continued and enhanced government support will be needed to further agroforestry adoption. More emphasis could also be made in building support for carbon and other environmental service markets. The lack of enthusiasm for such markets is due in part because the group felt that insufficient technical capacity to design, implement, and monitor carbon projects was insufficient within the country. There is also concern that these programs may end up primarily benefiting donors or outside investors with little benefit or even a net cost to the local population. Small-scale demonstration projects with carbon markets or other payment for environmental service markets that produce sustained local benefits may reduce skepticism around this issue. Enhancing the technical capacity for implementing and monitoring such programs within Rwanda may also be constructive.

The results also indicate that extension services and coordination of agroforestry interventions need to be improved. More efforts at translating research and expert knowledge of agroforestry (and agriculture generally) could yield substantial benefits to adoption and implementation of agroforestry by smallholder farmers. Group participants indicated many agroforestry interventions are loosely coordinated and sustained over a short period of time. More sustained focus on agroforestry is needed to promote its expansion to significantly beneficial levels. An obvious strategy to address the threat of population growth is for the government to encourage both more productive forms of agriculture and policies to encourage smaller population sizes. The government is currently working toward both of these goals (Wadhams 2010). Research on agroforestry systems appropriate to small plots might also be useful in this regard. Sustained and increased effort in these strategies could improve the prospects for agroforestry and its benefits in the country. In sum, agroforestry was seen as a net positive for Rwanda that could generate a flow of concrete benefits for smallholder farmers and make a significant contribution both to rural development and environmental protection and enhancement.

Finally, it should be noted that the results here reflect the perspectives of policy makers, researchers and extension specialists that have knowledge and interest in Rwandan agroforestry but do not include the perspective of smallholder farmers. The results should therefore be interpreted in light of other research that has focused on the perspectives smallholder farmers. Future research can utilize a variety of approaches to investigate the relative benefits of different agroforestry systems as well as the best strategies in different regions and landscapes in Rwanda. For instance, the eastern part of the country is much drier than other parts while the western part of the country is both more mountainous and wetter. Such variation will likely make the challenges faced by smallholder farmers as well as the most appropriate agroforestry practices and policy support options differ significantly between regions. Different demographic groups of smallholder farmers also will likely need different strategies and different approaches. For example, female-headed households, as a group, likely face different challenges in adopting any new agricultural approach such as agroforestry. Women often adopt fewer and cheaper agricultural inputs because such households tend to be poorer on average than male-headed households (Bidogeza et al. 2009). Research investigating the perspectives of various demographic groups of smallholder farmers would be useful in providing information on such differences Finally, studies utilizing small groups of experts or stakeholders such as this one can be combined with other studies utilizing economic analysis and related approaches to provide rich information about the benefits and challenges of agroforestry in Rwanda and elsewhere in the region. Such information in turn can provide policymakers guidance about needed policy support for various segments of the smallholder farmer population.

Acknowledgments Funding and support for this project was provided by the University of Kentucky, Wildlife Conservation Society, and the Institut des Sciences Agronomiques du Rwanda (ISAR). The authors would like to thank all the participants in the workshop for providing valuable insight into Rwandan agroforestry and making this project possible.

Appendix

Conducting a SWOT-AHP analysis is a three-step process (Kurttila et al. 2000; Masozera et al. 2006; Dwivedi and Alavalapati 2009). In the first step, possible SWOT factors relating to the proposed strategy or decision are identified. Human cognitive limits in conducting pair-wise comparisons generally limit the number of factors in a SWOT category to a maximum of ten (Saaty 1977). In the second step, pair-wise comparisons of factors within each SWOT category are made. Pair-wise comparisons are conducted separately for all factors within a category and a priority value for each factor is computed using the eigenvalue method. The factor with the highest priority value under each SWOT category is brought forward for comparison with the highest priority value factors from other SWOT categories. In the third step, participants make pair-wise comparisons of the four factors that are brought forward and a scaling factor or global priority value for each category is computed. Scaling factors and priority values are used to calculate the overall or global priority of each factor as shown below:

$$\begin{aligned}\text{Overall priority of factor}_{ij} &= \left(\text{priority value of factor}_{ij}\right)\\ &\quad * (\text{scaling factor of SWOT category})\text{ where } i\\ &= \text{number of factors in a SWOT category and } j\\ &= 4(\text{strength, weakness, opportunity, and threat}).\end{aligned}$$

The overall priority scores of all factors across categories sum to one and each score indicates the relative importance of each factor.

To estimate priorities, the results of the pairwise comparisons can be represented in a reciprocal matrix with the relative weight represented by a_{ij} and it's reciprocal, on the opposite side of the diagonal, as $1/a_{ij}$

$$A = a_{ij} = \begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_1 \\ \vdots & \vdots & \cdots & \vdots \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_n \end{bmatrix}. \tag{1}$$

In matrix A, rows represent the relative weight of each factor to the others. When $i = j$, $a_{ij} = 1$. When the transpose of the vector of weights w is multiplied by matrix A we get a vector represented by $\lambda_{\max} w$, where

$$Aw = \lambda_{\max} w, \quad \text{where } w = (w_1, w_2, \ldots w_n)^{\mathrm{T}} \tag{2}$$

where $\lambda_{\max}$ is the largest eigenvalue of matrix A and w is the transpose of the vector of weights.

Equation 2 can be written as

$$(A - \lambda_{\max} I)w = 0 \tag{3}$$

where I is the identity matrix. The largest eigenvalue, $\lambda_{\max}$, is equal to or greater then n or the number of rows or columns in the matrix A (Saaty 1977). The more consistent the responses are with each other the closer $\lambda_{\max}$ is to n. If all responses are perfectly consistent then $\lambda_{\max}$ equals n (Kurttila et al. 2000; Saaty 1977). Matrix A can be tested for consistency using the formula

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \quad (4)$$

$$\mathrm{CI} = \frac{(\lambda_{\max} - n)}{n - 1} \quad (5)$$

where CR is the consistency ratio, CI is the consistency index, and RI is the consistency index of a random matrix of order n. As a general rule, the consistency ratio should be kept to less then 10% (Saaty 1977).

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