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METHODS

Transition towards improved regional wood flows by integrating material flux analysis and agent analysis: the case of Appenzell Ausserrhoden, Switzerland

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Abstract

This paper discusses the integration of material flux analysis and agent analysis as the basis for a transition towards improved regional wood management in Appenzell Ausserrhoden (AR), a small Swiss canton located in the Pre-Alps of Switzerland. We present a wood flow analysis for forests, wood processing industries and consumption in AR, accounting for different wood products. We find that the forest is currently significantly underutilized although there are sizeable imports of wood and fuel to this small region. The underutilization of the forest contributes to a skewed age distribution, jeopardizing long-term sustainable development of the forest, as the fulfillment of its protective and production function are likely to be at risk. The wood resources, however, are capable of satisfying current wood demand among the population of AR and wood could even be exported. Underutilization has two main causes: first, wood prices are so low that harvesting trees is a money-losing proposition; second, consumer wood demand and the current supply from forest owners are not aligned. Furthermore, cultural values, lifestyle trends and traditions make an alignment of supply and demand difficult. Consensus and strategy building with the relevant stakeholders on the basis of the results obtained from the wood flow analysis and agent analysis is a reasonable next step to take. We conclude that wood flow analysis combined with agent analysis provide a useful and straightforward tool to be used as the basis of a transition process towards improved regional wood flows, which in turn should contribute to sustainable forest management.

Keywords: Agent analysis; Material flux analysis; Regional wood management; Transition process; Sustainable forest management

1. Introduction

Forests are multi-functional ecosystems. In Switzerland, the law takes this multi-functionality into account and declares that forests have to fulfill the functions of (i) protection; (ii) production; and (iii) welfare (Swiss Forest Law, Art. 1c). The protective function regards the forest as a shield against avalanches, erosion and rock fall and is most important in the alpine and pre-alpine regions. Production has to be carried out sustainably, a criterion implemented with the first Swiss forest law in 1870 and still valid today.

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The welfare function includes biodiversity conservation, CO_2 reduction, recreation and environmental education. Clearly, the Swiss forest law focuses on the utility of forests for humans.

Since 1992, Switzerland has committed itself to sustainable forest management (SFM) by signing the Forest Principles (Rio, 1992) and the resolution of the Ministerial Conference on the Protection of Forests in Europe (Strasbourg, 1990; Helsinki, 1993; Lisbon, 1998). In the latter, SFM is defined as the "stewardship and use of lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfill, now and in the future, relevant ecological, economic and social functions, ..." (Resolution H1, MCPFE, 1993). In 1998, six criteria and 20 associated indicators were defined to evaluate the implementation of the SFM guidelines (MCPFE, 1998).

A preliminary evaluation of Swiss forest development is presented in Table 1 (Brändli, 1999). Both forest area and stocks have been increasing, contributing to CO_2 fixation. The forest stock in Switzerland is considerably larger than in other European countries: it is 6 times larger than in Norway, 3.6 times larger than in Sweden, and 1.3 times larger than in Germany (BfS and BUWAL, 2001). Another positive development is the improvement of biodiversity. However, forest health, wood production, and forest stability have been developing negatively (Table 1). According to Brändli (1999), the main reason for this trend is that the age structure in forests has shifted from a relatively homogenously distributed one, i.e., equal share of area covered by trees of different age classes, towards a prevalence of older trees. A homogenously distributed age structure, however, is crucial for sustainable forest development as it (i) enhances the stability of forests, supporting their protective function and decreasing the risk of storm damage; (ii) allows for a continuous harvest rate, ensuring the production function; and (iii) supports biodiversity as an adequately managed forest is less dense and allows more species to grow. Thus, in order to ensure the long-term sustainable development of Swiss forests, it is necessary to improve their current age structure (SAFE, 1998; SAEFL, 1998, 1999).

A homogeneously distributed age structure is closely linked to forest management. Indeed, in the period from 1989 to 1999, only 65% of the stock growth was harvested and only 20% of the necessary encroachments were carried out (Brändli, 1999). In addition, only about 64% of the national wood demand was satisfied with Swiss wood (Schmithüsen, 2000). The gap between the potential and harvested wood volumes is due to structural problems and unfavorable economic conditions, e.g., (i) decreasing net wood prices; (ii) small forest and wood processing enterprises; and (iii) lack of official wood quality criteria (Schader and Messerli, 1995; SAEFL, 1999). It is thus clear that if sustainable forest management is to be successful, it has to be linked with wood management.

Since forest regulation in Switzerland currently takes place at the cantonal level (Swiss Forest Law, Art. 16, Art. 20–25, Art. 27), alternative approaches have been discussed, namely whether and how a transition from sector planning which tries to separately optimize forest management, wood manage-

Table 1
Evaluation of the state of Swiss forests with respect to the Helsinki criteria (adapted and shortened from Brändli, 1999)

Helsinki criteria/indicators applied in Switzerland	Development (1989–1999)
Forest resources and global carbon cycle	positive
• Forested area	• increasing
• Wood stock; CO_2 stock in forests	• increasing
Forest ecosystem health and vitality	decreasing
• Tree or forest damage	• increasing
• Compulsory use (due to storms)	• increasing
Productive function (wood and non-wood)	decreasing
• Stock growth/stock use	• increasing (too low a harvest rate)[a]
• Harvesting cost/revenue	• decreasing
• Age structure	• negative for production function
• Regeneration area	• not sufficient
Biological diversity of forest ecosystems	increasing
Protective function (soil, water, avalanches)	constant
• Current protection level	• good
• Damage; stability	• increasing damage, less stability
• Development (coverage of forest roads)	• good
• Maintenance	• deficient
Socio-economic function	good
• Area for recreation; forest beauty	• increasing

[a] Data for 1993 to 1995.

ment, and consumption, to an optimized regional wood management might support both a more sustainable forest and wood management (Müller, 1999; SAEFL, 1999; H. Hess, personal communication, 2002). Such a transition process should consider the current situation and define strategies and measures to cope with changing conditions and claims on forests and forest products.

In this paper, we discuss the contribution of material flux analysis (MFA) and agent analysis to the transition towards improved regional wood flows. We postulate that the integration of these two methods will provide important insights and thus lead to a thorough understanding of the system as the basis for a successful transition process. MFA has been used to analyze and model material balances of corporations and urban regions in industrialized and developing countries (Ayres, 1978; Baccini and Brunner, 1991; Binder et al., 1997, 2001), to describe regional wood management of the Swiss lowlands (Müller, 1999) and to analyze the generation of waste in regional systems (Schwarzenbach et al., 1999; van der Voet et al., 2002). The analysis of agents and agent networks, on the other hand, although long established within sociology (Wasserman and Faust, 1994), has only recently started to be explored in connection with environmental topics (Axtell et al., 2002; Binder, 2002; Hirsch Hadorn et al., 2002; to some extent, Spangenberg and Lorek, 2002). The identification and analysis of agents who are related to the material flux analysis seems a promising approach for both studying problems in environmental sciences and developing strategies and measures within transition processes.

In this paper, we present an approach to integrating material flux analysis and agent analysis as support for the transition process towards improved regional forest and wood management in the region of Appenzell Ausserrhoden (AR), a pre-alpine region in Switzerland. More specifically, we (i) analyze the main issues in regional wood management based on a regional material flux analysis; (ii) identify the key agents determining the main issues; (iii) investigate the agent interactions and the structure of their regulation; and (iv) discuss the value of wood flow analysis and agent analysis for supporting transition processes.

The paper is structured as follows: after a first synopsis of the main characteristics of the region and its forest, we apply the method of material flux analysis to single out the main issues in the regional wood flow, then identify the key agents in those issues and discuss their interactions and the structure of the regulation.

2. The study area

2.1. Appenzell Ausserrhoden (AR)

With an area of 24,000 ha AR is one of the four smallest cantons in Switzerland. A canton has an own constitution, legislation, and government and corresponds to a state. AR lies in the northeastern part of Switzerland. It is a pre-alpine area with an altitude ranging from 400 m above sea level (shore of Lake Constance) to 2500 m above sea level (peak of the Säntis). In 1999, AR had a population of 53,800 inhabitants. Land use was 56% agriculture, 33% forests and 11% settlements and unproductive area. About 8% of the workforce worked in the first sector, and 4% were indirectly dependent on the forest related economy; e.g., wood processing industries (Deér and Gugger, 2002). From a resource perspective, AR, as a rural canton, could play an important role in supplying urban areas with wood, water, and ecosystems services (Hofer, 2001).

2.2. Historical development of the forest in AR

Originally AR was a completely forested area. After the demise of the Roman Empire, Alemanni settled in AR in the 8th century. Settlements were loose-knit, with each family living on their own parcel of land including a piece of forest. This changed as early as the 18th century when AR specialized in textile production and became one of the most industrialized areas in Europe while simultaneously maintaining pasture farming. The greater demand for workers led to increased population density followed by a higher demand for wood for buildings, furniture and firewood. In the late 18th century, forests only remained along the riverbeds embedded in narrow canyons and on the

Table 2
Forest structure in AR in 1995

Wood stock according to age groups		Forest area according to development stage and age		
Age	Stock (%)	Development stage	Average age	(%)
0–40 years	4	Young stand	0–15	4
41–80 years	23	Pole forest	16–40	11
81–120 years	55	Young timber tree[a]	41–65	26
More than 120 years	3	Middle-age timber tree[b]	65–95	26
No defined age	15	Old timber tree[c]	96–. . .	8
		Mixed stand		21
		Not defined		4

[a] Broad-leafed trees (41-60), conifers (41-0), (source: Ettlinger, 2001).
[b] Broad-leafed trees (61-90), conifers (71-100), (source: Ettlinger, 2001).
[c] Broad-leafed trees (91–), conifers (100–), (source: Ettlinger, 2001).

mountain peaks so that in 1850 only 16% of the cantonal area was covered with forests. At that time the average age of the trees had decreased to about 30–40 years. As a reaction, in 1836 a community group founded an NGO (Waldbauverein) which brought grazing land and reforested it with spruce. This was the first movement towards forest protection. In 1877, Swiss government implemented its forest policy, i.e., every canton had to employ a forest warden who had to ensure forest area maintenance. Furthermore, other fuels replaced wood. Thus, the pressure on forests decreased and the wooded area regenerated. There followed a time of wood plantations and harvesting until in the early 20th century, a storm damaged the forests so heavily that spruce sprouts had to be imported from Germany for reforestation. As a result, a more modest use of the forest was decided upon (Ettlinger, 2001).

2.3. Forest structure

The main tree type in AR is imported spruce (55%), followed by fir (17%) and beech (15%). The relation between stock and age is skewed: old trees of 80–120 years dominate the wood stock (55%), followed by trees with ages between 40 and 80 years (23%). The rest make up for the other 22% (Table 2). The age distribution by area is also skewed with trees up to 40 years covering only 15% of the area. This age distribution does not contribute to sustainable forest development (see Introduction). According to the cantonal forest officer (R. Sommerhalder, personal communication), it can already be observed that the AR forests do not completely fulfill their protective function. Indeed, severe storm damage to forest and dwellings have occurred in the last years. In addition, the accumulation of uncollected storm wood in the riverbeds is for a cause of floods.

2.4. Property structure

About 74% of the total forest is private property (Table 3), whereas in Switzerland generally, only 32% of the forest is privately owned (Brassel and Brändli, 1999). Most of this belongs to private households (to a large extent farmers), who own on average tiny sites of 1.2 ha/cap and possess 67% of the total forest area, whereas corporations own about 7%. Among the public owners, communities own about 14%, Canton and State together about 5%, and other public organizations about 8% of the forest area (Ettlinger, 2001).

2.5. Wood prices

Over the last 10 years, net wood prices have constantly been decreasing. Price indices for hardwood (from broad-leafed trees) have decreased by 22% from 1992 to 2002/3, while prices for softwood (from conifers) have decreased by 28% (BfS and BUWAL, 2001). Prices for firewood and pulpwood

Table 3
Property structure of forest areas in AR

Public forest owners			Private forest owners		
State	27 ha	0.4%	Corporations	483 ha	6.5%
Canton	349 ha	4.7%	Private persons	4983 ha	67.1%
Communities	1010 ha	13.6%			
Other public organizations	576 ha	7.7%			
Public total	1965 ha	26.4%	Private total	5466 ha	73.6%

Source: Ettlinger (2001).

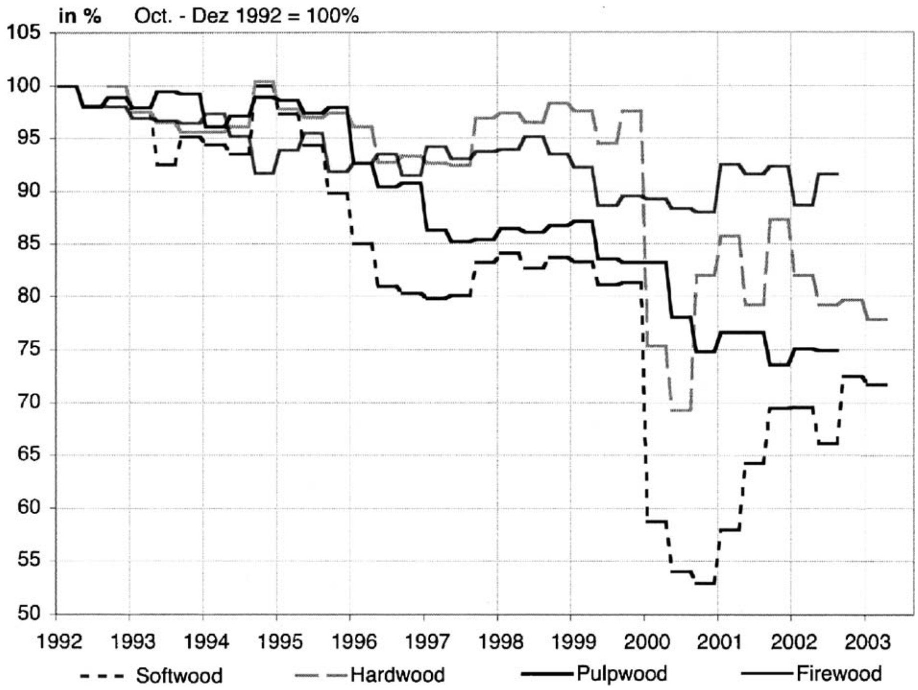

Fig. 1. Wood price index for softwood, hardwood, pulpwood and firewood.

have also decreased, reaching, in 2001, 91%, and 75% of the 1992 price, respectively (Fig. 1).

3. Materials and methods

3.1. The transition process

Transition processes have become a key topic in regional management and development (Rotmans et al., 2000, 2001; Ravetz, 2000; Scholz and Tietje, 2002), and a typology for planning and managing transition processes in regions has been developed (Thierstein and Walser, 2000). Extensive experience on urban and regional development has also been gathered in 10 large-scale studies at the Swiss Federal Institute of Technology (ETH Zürich). These studies are characterized by a process of mutual learning between academic theory and practice with 50–100 participants from university and 100–200 participants from practice. The basis of these studies is the application of formative methods (Scholz and Tietje, 2002) in goal formation, system representation, system evaluation and consensus building to the transition process (see Mieg, 2000; Scholz et al., 1997, 2002).

Three steps characterize a transition process (Scholz and Wiek, 2002): (i) system understanding; (ii) goal formation; and (iii) backward planning (Fig. 2). In the first step a thorough understanding of the current system and its properties is attained. It includes knowledge of material flows and investigation of key agents and agent interactions (initial focal variables), and is thus the basis for a successful transition process.

In the second step, the future state of the system is determined, that is, goals for the development of the system are set (terminal focal variables). Goal formation is an extremely important issue in any decision and problem solving process (Brunswick, 1950; Johnson-Laird, 1983; Scholz, 1987; Jungermann et al., 1998). The goals are usually set in a consensus building process with the agents or stakeholders identified in step 1 (Susskind et al., 1999) or derived from consensual documents. In the latter case, preliminary goal setting can precede step 1. In this paper, preliminary goals for the transition process were derived

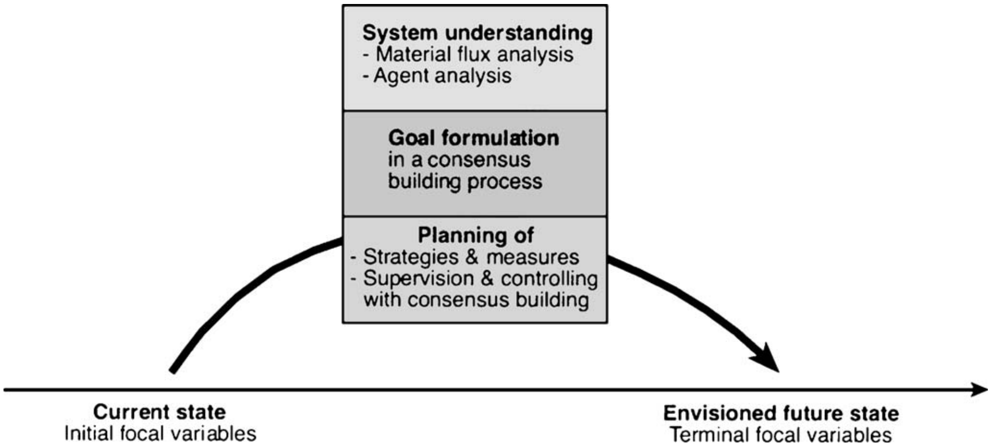

Fig. 2. The transition process departs from the current system and practice (initial focal variables) and leads through a complete negotiation and implementation process, which finally leads to a changed practice (terminal focal variables).

from legal guidelines and international agreements (see Introduction).

The two preceding steps are the foundation for planning strategies, measures and supervision criteria (step 3). In this step, the different interests of the agents have to be negotiated. An important part of this negotiation is again a consensus building process. After the agents have agreed upon strategies and measures to take, supervision criteria and instruments have to be designed to measure the success of the strategies. This monitoring process is most important, and should be planned from the very beginning, covering the efficiency of the whole process (Ossadnik, 1996; Heitzer, 2000; Scholz, 2001).

3.2. Material flux analysis (MFA)

3.2.1. Background

Material flux analysis (MFA) is a method to describe and analyze the material balances of a system, e.g., an industry or a region (Baccini and Bader, 1996; for a review on MFA see Scholz and Tietje, 2002, pp. 271). MFA is based on the law of conservation of matter. A MFA model is defined by a system boundary, internal and external balance volumes (“processes”), goods or materials, and their fluxes between different processes. A material is defined as an element or chemical compound, a good is a compound forming a product. Material fluxes between various processes P_i and P_j $i,j=1, \ldots, n$, are modeled by transfer-coefficients k_{ij}, $i,j=1, \ldots, n$, which define the proportions of the total inputs into the process P_i which are transferred to other processes P_j, whereas $\sum_{j=1}^{n} k_{ij} = 1$.

3.2.2. System analysis for the wood flows in Appenzell Ausserrhoden

Fig. 3 shows the system analysis for wood flows in Appenzell Ausserrhoden. The system boundary is the political border of AR. The system is composed of 6 processes and 20 flows. In the forest, biomass is produced from CO_2. The forest owners decide to what extent the trees are harvested and what type of product is produced. The direct outputs of the forest are: (i) round timber, which is either used by the regional sawmills (raw timber processing) or exported to other regions; (ii) pulpwood, which is exported for production of paper and cardboard; and (ii) firewood, which is either used by regional energy-producing industries or exported. Forest owners also use some of the harvested timber themselves. The specific use is not clear; however, we assume that the largest part is used as firewood.

Within the region, sawmills process the regional and imported round timber to sawn wood, wood residues and firewood. According to BfS and BUWAL (1999) in 1996, 17 sawmills were operating in AR. Six of them were run as a main income source, 11 as a companion plant. From 1991 to 1996 the number of sawmills in AR decreased from 21 to 17. Sawn wood is either further processed in regional wood processing industries or

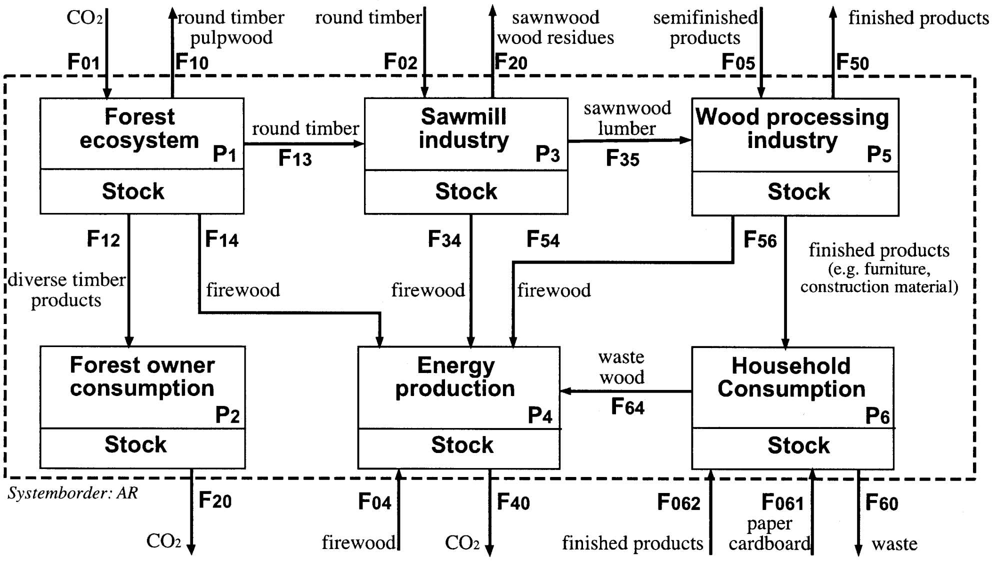

Fig. 3. System analysis of the regional wood flow in Appenzell Ausserrhoden.

exported. Firewood is delivered to regional energy production, whereas wood residues are exported.

Wood processing industries in AR consist of joinery, furniture and parquet industries, as well as carpentry and timber construction. There is no paper and cardboard industry in AR. Wood processing industries (i.e., intermediate and final wood processing industries) also import, in addition to sawn wood, semi-finished products and produce and distribute furniture, products for self-assembly and construction material.

These products are consumed by private households or exported to other regions. Private households import paper and cardboard as well as finished products, while exporting wood waste material and waste paper and cardboard. The process of energy production consists of plants that produce energy from firewood, delivered from the forest ecosystem, saw mills and wood processing industries as well as waste wood from private households. Private furnaces are included for simplicity in the energy production process.

3.2.3. Mathematical formulation of the quasistationary model

P_i, $i=0,1, \ldots, 6$, denote the different processes. The external processes P_0, i.e., the processes outside the system borders, are not specified. The material fluxes F_{0j} are the system inputs and F_{i0} are the system outputs, $i,j=1, \ldots, 6$. The outputs and the fluxes between the processes F_{ij} can be calculated by means of transfer coefficients (see above). Thus, any material flux of the inner system border is defined as:

$$F_{ij} = k_{ij} \sum_{m=0}^{6} F_{mi}, \quad i = 1, \ldots, 6. \tag{1}$$

For the dynamic formulation of MFA systems see Baccini and Bader (1996), Kleijin et al. (2000), Binder et al. (2001), and van der Voet et al. (2002).

3.2.4. Data sources and assumptions for the wood flow analysis

Table 4 presents the data sources and their error margins for each process and the corresponding fluxes. It was assumed that for all processes except forest, forest owners and private households, stock change is equal to 0.[1] We adapted the data for the reference year 1995.

3.2.4.1. Forest ecosystem.

The data for forest stock, stock change and harvest was obtained and validated via two sources. First, the Swiss national forest inven-

[1] It can be assumed that over a year the wood stock of sawmill owners is constant and does not increase within the year. For our analysis the absolute level of this stock is not of interest.

Table 4
Data sources and error margins for fluxes and stocks

Flux/Stock	Formulae	Value	Error margin (%)	Data source
Forest stock	P_1	3,550,000 m^3	5	Brassel and Brändli (1999)
Stock change	dP_1/dt	+42,000 m^3/a	5	Ettlinger (2001)
Import: CO_2	F_{01}	200,200 t	5	Eq. (2)
Diverse products	F_{12}	3900 m^3/a	7	Ettlinger (2001)
Round timber	F_{13}	17,400 m^3/a	7	Ettlinger (2001)
Firewood	F_{14}	2300 m^3/a	7	Ettlinger (2001)
Export: round timber	F_{10}	4400 m^3/a	7	Balance calculation
Forest owners' stock	P_2	–	–	Not known
Stock change	dP_2/dt	2000 m^3/a	20	Ass: $dP_2/dt = dP_6/dt$
Export: CO_2	F_{20}	1400 m^3/a	20	Process balance
Sawmills' stock	P_3	–	–	
Stock change	dP_3/dt	0	0	Model assumption
Import: round timber	F_{03}	1900 m^3/a	25	Interviews
Firewood	F_{34}	2500 m^3/a	10	BfS and BUWAL (1999)
Sawn wood	F_{35}	9400 m^3/a	10	BfS and BUWAL (1999)
Export: sawn wood, etc.	F_{30}	7400 m^3/a	25	Interviews
Energy production	P_4	–	–	
	dP_4/dt	–	–	Model assumption
Total firewood input		14,100 m^3/a	10	BfS and BUWAL (1999)
Import: firewood	F_{04}	5800 m^3/a	5	Process balance
Export: CO_2	F_{40}	11,100 m^3/a	5	Eq. (2)
Wood processing	P_5	–	–	
Stock change	dP_5/dt	0	0	Model assumption
Total production		14,600 m^3/a	10	BfS and BUWAL (1999)
Import: semi-finished	F_{05}	6800 m^3/a	25	Interviews
Firewood (residues)	F_{54}	3400 m^3/a	10	BfS and BUWAL (1999)
Finished products	F_{56}	6400 m^3/a	20	BfS and BUWAL (1999)
				Interviews
Export: products,	F_{50}	6400 m^3/a	25	Interviews
Household stock (M_6)	P_6		30	Müller (1996, 1999)
dM_6/dt	dP_6/dt	+1% per a	50	Müller (1996, 1999)
Waste wood	F_{64}	12,000 m^3/a	30	Müller, (1996, 1999)
Import: paper, cardboard	F_{061}	15,800 m^3/a	10	BUWAL (1998)
Import: products	F_{062}	6400 m^3/a	10	BUWAL (1998)
Export: waste, including paper	F_{60}	28,600 m^3/a	30	Process balance

tory was performed in 1995 (Brassel and Brändli, 1999), and second, also in 1995, forest inventories were performed in more detail at cantonal level (Ettlinger, 2001). CO_2 input was calculated using total growth of broad-leaved and confers in the region, density and carbon content of timber by tree type.

$$CO_2/\text{year} = (V_i^{t=1} - V_i^{t=0})*\rho_i*S_C*44/12 \qquad (2)$$

where, CO_2/year: yearly CO_2 fixation by the trees; $V_i^{t=r}$: stock of tree type i in m^3 at time t, $r=1,\ldots,T,\ldots$, $i=1,\ldots,K$; ρ_i: density of tree type $i, i=1,\ldots,K$; S_C: share of carbon in timber (0.47; Pingoud and Lehtilä, 1997).

3.2.4.2. Forest owner consumption. The amount of wood consumed by forest owners was obtained from the cantonal forest statistics (Ettlinger, 2001).

3.2.4.3. Sawmill industry (raw timber processing). The data about the total amount of timber processed in sawmills were obtained from the Swiss Federal Office for Statistics (BfS and BUWAL, 1999). The transfer-coefficients from timber to sawn wood, waste wood and firewood were also available. In addition, 9 of the 17 sawmill owners were interviewed. They were asked about the percentage of timber imported and round timber and pulpwood exported to wood processing industries.

3.2.4.4. Wood-processing industries (intermediate and final wood product production). There are no regional statistics for the wood processing industries. The wood flows were estimated via two sources. First, the national statistics for the wood processing industries were utilized and adapted to the existing industries in the region. Second, we validated these results with the average per capita demand for the products (BUWAL, 1998). Finally, we conducted interviews with owners of these industries about import and export of sawn wood and products. The transfer-coefficient from sawn wood to waste wood, i.e., firewood and products were derived from national industry studies (BfS and BUWAL, 1999).

3.2.4.5. Household consumption. As no regional consumption statistics exist, we assumed that household consumption in AR is consistent with Swiss average consumption (BUWAL, 1998).[2] Since AR has no paper and cardboard industry, paper and cardboard demand is covered by imports. The amount of imported finished products is calculated as the total demand for finished products minus the supply by local wood processing industries (see above). Household stock and stock growth were estimated according to Müller (1996). Stock growth is assumed to be 1% per year. The waste flux is thus equal to total input minus stock growth. Interviews with regional experts indicate that 90% of waste wood materials are exported and about 10% are used for energy production (Müller, 1999).

3.2.4.6. Energy production. The amount of firewood used for energy production is the sum, of (i) firewood provided directly from forests; (ii) wood residues from sawmills and wood processing industries; (iii) waste wood from private households; and (iv) imports.

3.3. Agent analysis

Agent and agent network analysis are well established within the field of sociology. Several types of agent analyses exist, ranging from qualitative analysis to quantitative, statistical analysis (Wasserman and Faust, 1994; Scott, 2000). In this paper, we focus on a qualitative approach linked to a graphic representation. The structure of regulation among the agents was determined and classified according to the structuration theory of Giddens (1979), which has been applied mostly in the field of organizational theory (Barley, 1990; Orlikowski, 1992; Edwards, 2000; Jones et al., 2000). Hirsch Hadorn et al. (2002) combined the structuration theory with life cycle analysis. Binder (2002) applied the structuration theory to developing countries to identify options and restrictions within the consumption of interiors of different social strata in Tunja, Colombia.

In this paper, the structure of regulation was divided into economics or market related interactions (allocative resources), legislation (legitimation), and cultural values (signification). It should be noted that the agent analysis relates directly to the issues determined in the wood flow analysis, and thus, is not a sociological analysis per se. First, the agents affecting those issues were identified by expert interviews and literature analysis. Second, standardized interviews were conducted with a sample of these agents to analyze their

Table 5
Data sources for agent analysis

Method	Involved agents	Issues discussed
Standardized interviews (by phone)	sawmill owners (9 of 17 interviewed; 50%) wood processing industries (28 of 108 interviewed; 26%)	percentage of regional wood used percentage of products sold within the region of AR type of industry and size of industry (family, Nr. of employees)
Round table	forest owners	main problems of the wood chain
discussion	sawmill owners	main influences on the wood chain
(Total 13 persons)	wood processing industries consumers	relevance of national programs (e.g., wood certification, sustainable forestry, EnergieSchweiz)
Expert interviews (face to face)	forestry service of the Canton Zürich (Chief of forestry planning)	results from wood flow analysis results from agent analysis
	forestry service of Canton AR	structure of regulation
	(Chief of forestry service)	strategies for improving regional wood management
	Professor of Forest Policy and Forest Economics, ETHZ	

[2] This assumption has been made for most regional MFA studies in Switzerland (see Müller, 1996, 1999; Hug, 2002).

relation to other agents within the wood chain (ratio of imported versus regionally produced wood, ratio of exported versus wood products sold in the region). These data were also utilized for the wood flow analysis (Table 4). In a roundtable discussion (Lang, 2002) with forest owners, wood processing industries, and consumers, first types of interactions and regulation structures were identified. Third, based on these data, an agent analysis was set up, which was thoroughly discussed with experts from politics and forestry research (Mieg and Brunner, 2001). The agent analysis was reviewed and complemented. Finally, first strategies were discussed (Table 5).

4. Results

4.1. Wood flow analysis

Fig. 4 presents the wood flow of AR for the year 1995. The forest stock is about 3.55 million m^3 corresponding to 470 m^3/ha, and thus about 100 m^3/ha higher than the Swiss average. A balanced forest in this area, however, should have a stock of between 300 and 400 m^3/ha (H. Hess, 2003, personal communication). The stock grows each year by 70,000 m^3, of which only 28,000 m^3 (i.e., 40%) are utilized; in Switzerland on average 65% of the stock growth is harvested (Ettlinger, 2001). Thus, the forest development in AR is not likely to meet the criteria of SFM, as the stock is too high, the harvest rate too low, and the age structure skewed towards older trees (Table 2). Incentives for increasing wood harvest should focus on private forests as they are less intensively managed than public ones. Whereas in public forests from 1996 to 2001[3] the average harvest of wood was 6.4 m^3/ha, in private forests it was only 4.2 m^3/ha, leading to an overall average of 4.6 m^3/ha for AR. This harvest rate is 2/3 that obtained in Switzerland for the period of 1985 to 1995 and nearly half that of the pre-alpine region.

Sixty-two percent of the harvested wood (17,400 m^3) is delivered as round timber to local sawmills, 8% is used for local energy production; forest owners keep 14% for private use, and only 16% is exported for paper production. Sawmills process mostly locally grown timber (90%) and deliver about half of their products to the regional wood processing industries. The wood residues (13%) are used regionally as firewood; about 38% of their products and residues are exported.

Wood processing industries use 9400 m^3/year (58%) of the regional wood, the rest are imported semi-finished goods, or other wood types (total 6800 m^3/year). The products of these industries are used for construction (63%), and for "3/4 products" and furniture (37%).

Within AR, 6400 m^3/year (40%) of their products are consumed, the same amount is exported, and 3400 m^3/year (20%) are wood residues used for energy production.

Table 6 presents the final demand for wood products among private households. Only 34% (14,600 m^3/year) of the demand is covered by regional resources. As paper and cardboard cannot be produced in the region, the maximum household demand, given the current consumption structure, lies at 27,400 m^3/year. That is, wood demand based on the current wood consumption and export structure of AR stands at a maximum of 55,400 m^3/year (stock growth is 70,000 m^3/year). Therefore, changes in consumption structure, towards greater wood consumption and/or increased exports are necessary to support sustainable forest management in the long-term.

The following issues concerning the regional wood and forest management in AR can be derived from the wood flow analysis performed above:

4.1.1. Underutilized forests (increasing wood stocks)

The forests in AR are underutilized despite considerable imports of wood and wood products into the region. The imported amount of 42,000 m^3 corresponds to the unutilized stock growth of forests in AR. About 60% of these imports could potentially be covered by regional wood sources. Sustainable forest management, however, would require a harvest beyond this amount.

4.1.2. Wood import by wood processing industries (40%)

Wood processing industries import about 40% of their wood requirements and supply only about 50% of the regional demand. An interesting fact here is that

[3] Data from the period 1985 to 1995 were not available, but according to the cantonal forest officer the harvest rates were even lower than those for the period from 1996 to 2001 (R. Ettlinger, personal communication, 2002).

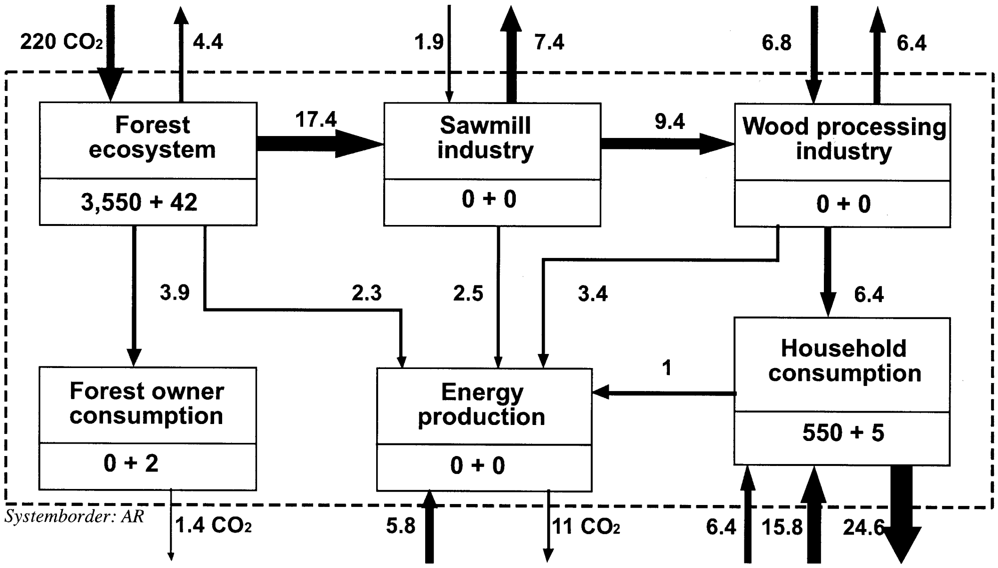

Fig. 4. Wood flow in Appenzell Ausserrhoden for the year 1995 (Stock in 1000 m^3; wood flow in 1000 m^3 wood/year; CO_2 flow in 1000 t CO_2).

family and small wood processing industries tend to use regionally produced wood and sell their products within the region whereas industries with more than 10 employees import most of their wood and export their products.

4.1.3. Import of wood for energy production

Only 33% of the regional demand for firewood is supplied by regional wood resources. As firewood production is a byproduct of the timber and wood processing, increased use of regional wood by sawmills wood processing industries would imply an increased availability of firewood.

Table 6
Final demand for wood products in AR in 1995

Product	Percentage[a]	Consumed in AR (1000 m^3/year)[a]	Production in AR
Energy	33%	14.1	8.2
Paper and cardboard	29%	12.5	none
Construction	22%	9.3	6.4
Furniture	7%	3	
Packaging	7%	2.8	no
Do it yourself	1%	0.5	no
Others	1%	0.5	no
Total	100%	42.7	14.6/34%

[a] Calculations based on BUWAL (1998).

4.2. Agent analysis

4.2.1. Key agents

The key agents are defined as stakeholders who determine or regulate the three issues which emerged from the wood flow analysis (Table 7). Forest owners directly influence *underutilized forests*. Cantonal and

Table 7
Key agents determining the main issues in regional wood management (source: own investigation)

Issues	Key agents
Underutilized forests (increasing stock)	Forest owners (D) Cantonal and federal government (I) Consumers and construction industries (I)
Wood import by wood processing industries	Wood processing industries (D) Sawmill owners (I) Consumers and construction industries (I) Forest owners (I)
Import of wood for energy production	Energy industry (D) Forest owners (I) Wood processing industry (I) Sawmill owners (I) Consumers and construction industries (I) Textile industry (I)

D, direct influence; I, indirect influence.

federal government regulate forest management through legislation and subsidies. Agents involved in demand, such as consumers (e.g., private households) and construction industry, have an indirect effect on forest stock. *Import of wood by wood processing industries* is directly determined by the wood processing industries. They are driven by the demand of consumers and construction industries and by the regional supply. *Import of wood for energy production* is related to the energy industries. It is influenced by the demand for wood energy and by the supply from wood processing industries and forest owners.

4.2.2. Agent interaction and structure of regulation

Fig. 5 presents both the main interactions among the key agents (regarding the demand for wood and wood products) and their structure of regulation. Three regulatory structures were identified in the analysis: *market mechanisms* (related to allocative resources), legislation (related to legitimation), and *cultural values* (related to signification). The agents' interactions are assumed to take place along these regulatory structures.

4.2.2.1. Underutilized forests. Forest owners are influenced by the three regulatory structures mentioned above. *Market mechanisms* represent both consumer demand and the competition of foreign products through wood prices (type and quality). They are the strongest structural element affecting forest owners. Low prices for fir, the dominant and native tree species in AR, make it difficult to obtain a positive revenue for timber and wood products. In addition, old trees dominate the forest structure (Table 2) and only a few sawmills have the necessary machinery for sawing thick trees. The demand of consumers and construction industries for other wood types (mainly from Nordic countries) cannot be satisfied because such tree types are not grown in this region. However, regional wood has comparable quality and could to a large extent replace the imported wood. In addition,

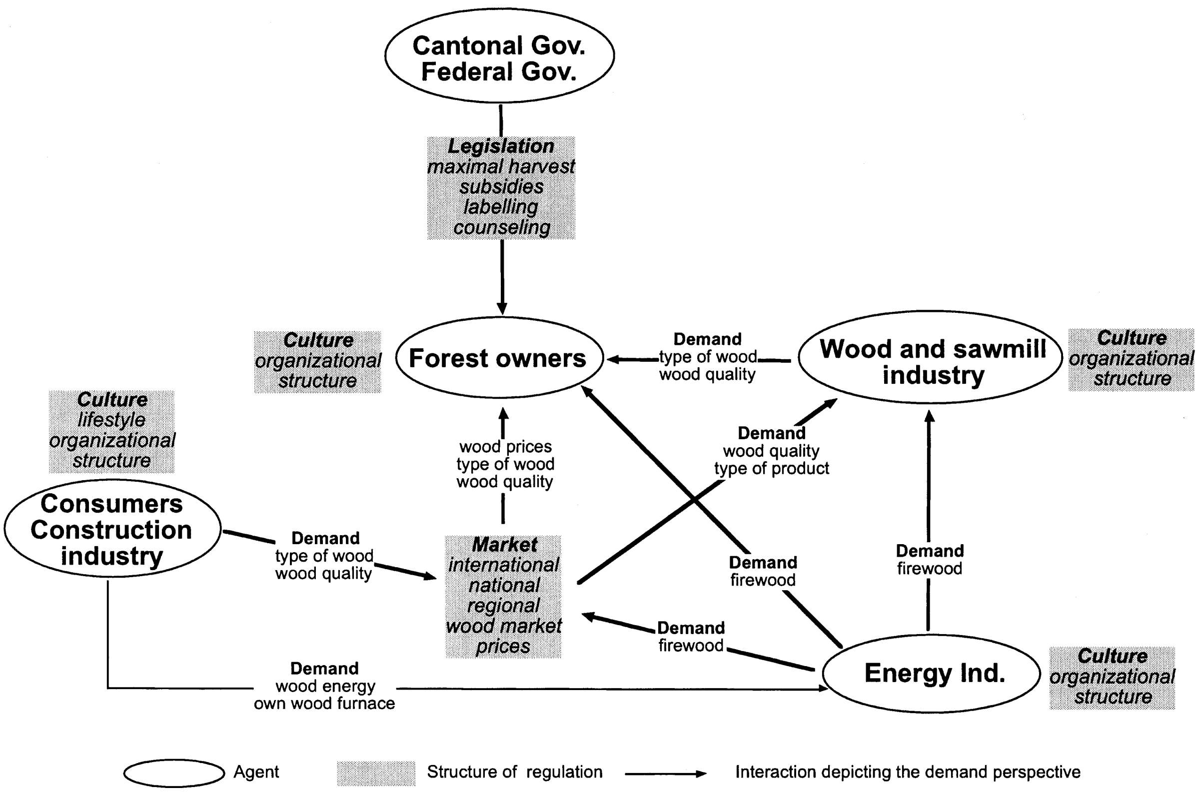

Fig. 5. Agents and their type of interaction and structure of regulation.

demand for wood type and quality changes within a time range of 10–20 years (lifestyle turnover), whereas trees grow in time periods of 50–100 years. Therefore, it is difficult for forest owners to adapt to demand changes. In other words, the demand for and the potential supply of wood are not aligned.

Federal and cantonal legislation provide some baselines on how to manage the forest. In AR the state forest law states (AR Cantonal Forest Law, Art. 16): "Forests have to be managed in such as way that they fulfill their functions as a matter of public concern; in particular forest owners have to: (a) maintain and foster forest stability; (b) foster native trees; (c) regenerate the forests; (d) achieve sustainability; (iii) conserve habitats for protected animals and plants,...". Forest owners can be obliged to manage their forest if its protective function is affected (Art. 17). Owners with more than 15 ha of forest have to work out a forest management plan (Art. 19b1). Owners of smaller plots are exempt if they harvest a maximum of 10 m^3/ha and year and are located outside a zone designated for protection (Art. 20-3). As 67% of the forest area is privately owned (with an average area of 1.2 ha/owner) and allocated to multi-functional forest, it is difficult to consolidate a common forest management strategy. Due to recurring natural disasters, one strategy that is currently being analyzed by AR forest officers is to change the allocation of about 50% of the forest area from multi-functional forest to protection forest. This would allow the enforcement of forest management (Art. 24). However, the administrative implementation might be costly given the forest property structure. Partnerships between forest owners, and sawmill industry could be an attractive option, in particular, when considering the export market of wood to Italy and Austria which accounted for 70% of the Swiss wood export in 2000 (BfS, 2003). The state administration and regulations could be framed to guide and facilitate these partnerships.

Cultural values, such as traditions and business relations play an important role in the agent system depicted above. Possessing a small piece of forest has a high traditional value for forest owners and thus, they are not willing, for example, to sell their forest. Informal and formal contracts between forest owners and, e.g., wood processing or energy industries, were essential for ensuring a minimum wood supply when wood was scarce (H. Hess, personal communication, 2002). Today they might be useful for assuring a minimum wood market for forest owners. In AR, interviews with wood processing industries showed that small family enterprises mostly still rely on these structures and buy most of their wood from local forest owners.

Wood import by wood processing industries and consumers is regulated by market mechanisms and cultural values. Concerning the former, wood processing industries are located in the chain between forest owners as suppliers and consumers and construction industry as demand. If they cannot satisfy the consumer demand with regional resources or if the latter are too expensive, they will choose to import different or cheaper wood. Here the relevance of consumers' cultural values becomes apparent: consumer demand depends on their lifestyle and the value accorded to regional versus imported wood, both affecting the regional wood flows. According to interviews and roundtable discussions with seven sawmill owners and statements of a board of six cantonal experts (Lang, 2002), there is currently a tendency to prefer wood from Scandinavian countries. This is due to the fact that architects and customers are skeptical about the quality of Swiss wood, which suggests that a Swiss wood label might be a good strategy to adopt. Another aspect is the increasing preference for semi-finished goods (or goods for self-assembly). These goods require small sized timber from young trees. Now the conflict for forest owners becomes apparent if they want to be able to supply the regional timber and wood industry: while stout timber from old trees is required for construction and related uses, small sized timber from young trees is needed for producing semi-finished goods.

4.2.2.2. Import of wood for energy production. Energy production industries are also influenced by market mechanisms, cultural values and legislation. Legislation has a significant effect: for the year 2003, the cantonal government of AR, within the EnergieSchweiz program (http://www.energie-schweiz.ch/bfe/de/energieschweiz/), decided to subsidize wood furnaces up to a capacity of 100 kW with a start-up subsidy of SFr. 3'000—(exchange rate: 1 Euro = 1.5 SFr.) and a production subsidy of SFr. 100—per kW produced. This will create an additional demand for firewood, which could be coupled with more wood use for other purposes, e.g., construction. Demand for firewood could also increase for the reason that, in signing the Kyoto Protocol, Switzerland committed itself to reduce CO_2 emissions and the Swiss Government has been signing CO_2 reduction agreements with all industries. For the regional textile industry, where energy makes up 40% of the production costs, a switch to regionally produced wood energy might be an attractive option. In 1992 the decree on air pollution (Luftreinhalte-Verordnung 814.318.142.1) became effective. It regulates the emissions from private and communal wood furnaces (Art. 5). Since then the emissions from wood furnaces have been reduced and energy efficiency has increased up to 90%, the one of oil being 92%. If the emissions of oil transport are considered, wood furnaces perform, from an environmental perspective, better than oil heating systems (A. Keel, personal communication). One issue, however, is the inappropriate use of such furnaces by private households, who tend to use the furnaces to burn their waste (A. Keel, personal communication).

4.3. Proposed next steps in the transition process

The integration of wood flow analysis and agent analysis has revealed the main issues, the related agents, and the corresponding structure of regulation. It has become clear that the goals and motivations of the different agents have to be consolidated if a change and optimization in the regional wood flow is to be achieved. The next steps to take are consensus building (Cormick, 1996; Susskind et al., 1999), design of strategies and measures with agent-related roles (Laws et al., 2001), and the design of supervision and monitoring tools (Scholz, 2001). We suggest that these steps should be institutionally framed to ensure the implementation of strategies. In our case, this framing could be based on current cooperation structures such as the Appenzeller Holzkette (Appenzell wood chain), which can be considered a typical example of a local initiative among key players to promote product development and distributions and thus has the potential to support the process of improving regional wood flows (Thierstein and Walser, 2000; Seintsch and Becker, 2002).

From the issues discussed above, one crucial area of negotiation emerges: how can the regional demand for wood and wood products be enhanced and better satisfied by regional supply potentials? This area of negotiation entails several aspects, such as (i) different time spans for changes in demand patterns and changes in forest structure; (ii) wood type and quality; and (iii) price structures. Thus, a negotiation process for improving regional wood flows will have to touch on some or all of these issues and compromises will have to be made by all parties.

Some of the strategies that emerged from first discussions with experts and which could be evaluated in a consensus-building process are:

- Relevance of long-term contracts between forest owners and wood processing industries.
- Utility of a regional wood label as a quality indicator (see BUWAL, 1999).
- Campaign for awareness of quality of regionally produced wood.
- Possibility of regional production of semi-finished products (also for export).
- Coupling increasing wood production for construction/furniture with firewood production.
- Increased use of firewood instead of oil for heating.

5. Utility of material flux analysis and agent analysis for the transition process

System analysis and understanding are postulated to be essential for successful transition processes (Ravetz, 2000; Scholz and Tietje, 2002; Scholz and Wiek, 2002). A good system analysis:

- Provides a thorough system understanding, which gives insight into the main problems and areas of conflict within the region.
- Provides a basis for strategy building within a consensus-building process, including the integration of the relevant stakeholders.

The integration of MFA with agent analysis first of all provides a quantitative analysis of the wood flow within the region. This allows identification of the main issues regarding regional wood management. By linking the key agents to the wood flows, we were able to determine both the stakeholders impacting on these issues and the areas of conflict or disagreement. Based on this information, an effective consensus-building process can be started where strategies can be discussed and their implication for the wood flow estimated. Once regulatory structures are known, the restrictions on implementing these measures can be identified and overcome. Graphic representation permits abstraction and thus provides a neutral but quantitative foundation for the process. Quantitative measures can be formulated, facilitating the monitoring process.

Obviously, the methods selected have some drawbacks. In the quantitative analysis, aspects of sustainable forest management, such as protection and biodiversity can only be considered indirectly. As shown in the Introduction, forest stock, stock growth, and age structure can be closely related to forest health, stability and production capacity, which are the basis for other functions. Thus, the quantitative analysis presented here relies on previous analyses where connection between different indicators were made. However, additional issues such as forest or landscape beauty, cannot be integrated in the quantitative analysis; they have to be brought in by the stakeholders during the consensus-building process. Multi-criteria decision making approaches (Scholz and Tietje, 2002, pp. 143) or consensus-building methods (Susskind et al., 1999) provide appropriate frameworks to integrate these issues. In addition, we consider that the strategies discussed must be thoroughly evaluated, including in particular economic and social parameters. In general, for environmental problems, the integration of MFA and agent analysis provides a basis that goes well beyond a purely environmental analysis, facilitating strategy and consensus-building among the stakeholders.

6. Conclusions

This paper has shown that the integration of material flux analysis and agent analysis is a sound basis for a successful transition process towards improved regional wood management because it provides:

- A quantitative analysis of the main issues related to improving regional wood flows
- An insight into the key agents determining those issues
- A systemic understanding of the structure of regulation affecting the interactions among the key agents

This thorough analysis can be used as the first step for a transition process, because (i) quantitative measures can be visualized and monitoring mechanisms can be set up; (ii) structural mechanisms that impede changing regional wood flows can be identified and strategies defined; and (iii) conflicts between the agents and the regional goals become apparent and, thus, potentially solvable.

The MFA and agent analysis of AR revealed that the forest is currently significantly underutilized although there are sizeable imports of wood and fuel to the region. The underutilization of the forest contributes to a skewed age distribution, jeopardizing long-term sustainable development of the forest, as the fulfillment of its protective and production functions are likely to be at risk. The wood resources, however, are capable of satisfying current wood and fuel demand among the population of AR. But to support sustainable forest management on a long-term, demand would even have to be increased or exports to other regions fostered. Underutilization has two main causes: first, wood prices are so low that harvesting trees is a money-losing proposition; second, consumer wood demand and the current supply from forest owners are not aligned. Furthermore, cultural values, lifestyle trends and traditions make an alignment of supply and demand difficult. As sawmills and wood processing industries, are situated between demand and supply they could act as catalysts by: (i) ensuring consumers a certain wood quality; and (ii) providing forest owners a market by establishing formal contracts (based on wood quality criteria), and (iii) fostering wood exports. Consensus and strategy building with the relevant stakeholders on the basis of the obtained results should evaluate the options for improving regional wood flows as well as a its contributing to sustainable forest management.

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