Transition process towards improved regional wood flow by integrating material flux analysis and agent analysis

The case of Appenzell Ausserrhoden, Switzerland (Working Paper, 39).

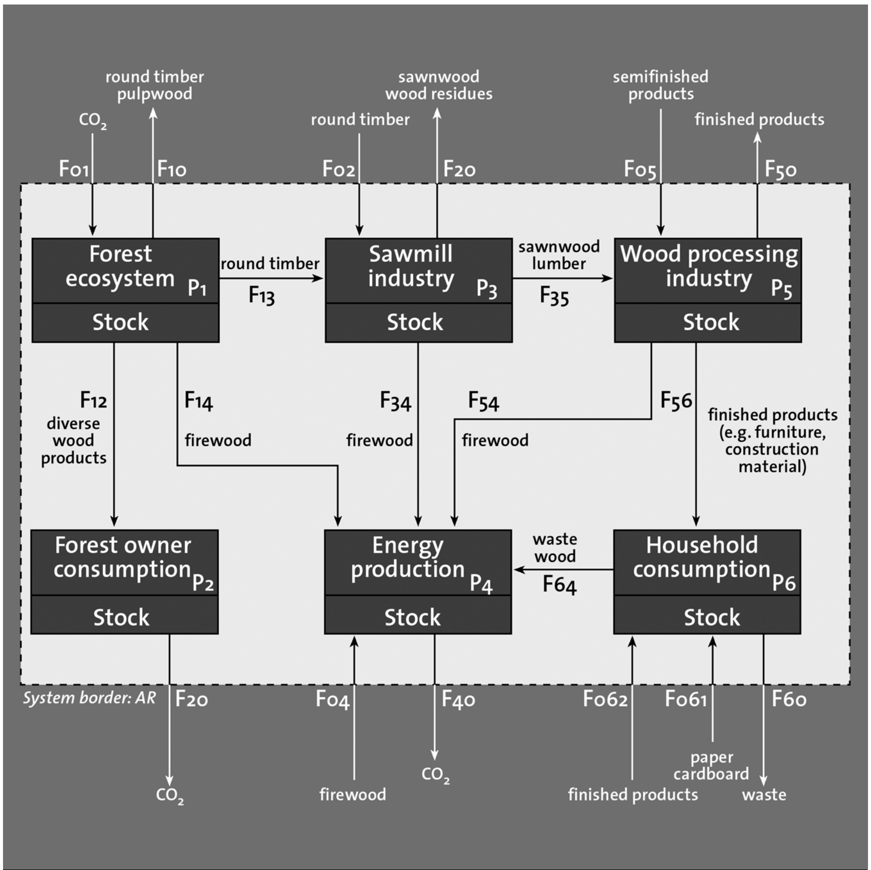
Author(s):
Binder, C.; Hofer, C.; Wiek, A.; Scholz, R.

Publication date:
2003

Permanent link:
https://doi.org/10.3929/ethz-a-004570841

Originally published in:
Working Paper / UNS 39

Working Paper 39



Transition process towards improved regional wood flow by integrating material flux analysis and agent analysis: The case of Appenzell Ausserrhoden, Switzerland

Claudia R. Binder,
Christoph Hofer,
Arnim Wiek, and
Roland W. Scholz

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

UNS
Umweltnatur- und Umweltsozialwissenschaften
Natural and Social Science Interface
Sciences naturelles et sociales de l'environnement

Natural and Social Science Interface (UNS)

Publisher:

Prof. Dr. Roland W. Scholz
Umweltnatur- und
Umweltsozialwissenschaften (UNS)
ETH Zentrum HAD
Haldenbachstrasse 44
CH-8092 Zürich
Tel. ++41-1-632 5892
Fax ++41-1-632 10 29
E-mail: scholz@uns.umnw.ethz.ch

Authors:

Claudia R. Binder
Umweltnatur- und
Umweltsozialwissenschaften (UNS)
ETH Zentrum HAD
CH-8092 Zürich
Tel. ++41-1-632 64 45
Fax ++41-1-632 10 29
E-mail: binder@uns.umnw.ethz.ch

Christoph Hofer
Umweltnatur- und
Umweltsozialwissenschaften (UNS)
ETH Zentrum HAD
CH-8092 Zürich
Tel. ++41-1-632 64 45
Fax ++41-1-632 10 29
E-mail: hoferc@student.ethz.ch

Arnim Wiek
Umweltnatur- und
Umweltsozialwissenschaften (UNS)
ETH Zentrum HAD
CH-8092 Zürich
Tel. ++41-1-632 52 60
Fax ++41-1-632 10 29
E-mail: wiek@uns.umnw.ethz.ch

Prof. Dr. Roland W. Scholz
Umweltnatur- und
Umweltsozialwissenschaften (UNS)
ETH Zentrum HAD
CH-8092 Zürich
Tel. ++41-1-632 58 91
Fax ++41-1-632 10 29
E-mail: scholz@uns.umnw.ethz.ch

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

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

Claudia R. Binder*, Christoph Hofer, Arnim Wiek, Roland W. Scholz

Contents

* Correspondence author

Abstract

This paper discusses the integration of material flux analysis and agent analysis as a prerequisite for a transition process towards improved regional wood management in Appenzell Ausserrhoden (AR), a small Swiss canton (i.e., state) with 93 square miles 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 wooden goods. We find, that the forest is currently significantly underutilized despite of considerable imports of wood and energy to this small region. The wood resources, however, would be sufficient to satisfy the total current wood demand of the population in AR. These wood resources are not being utilized for two main reasons: first, wood prices are so low that harvesting trees is a deficit; second, consumer wood demand (mostly hard wood) and the current supply by forest owners (mostly softwood) are not aligned to each other. In addition, cultural values and traditions such as organizational structure of forest owners, where each owner has a small piece of forest at 1.2 ha and lifestyle trends of consumers and construction industries make an alignment of demand and supply not an easy step to take. Consensus and strategy building on the basis of the obtained results of the wood flow analysis and agent analysis is a reasonable next step to take. We conclude that wood flow analysis combined with agent analysis is a useful and straightforward tool for ensuring a successful transition process towards improved regional wood flows.

Keywords: agent analysis, material flux analysis, regional wood management, transition process

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 protection function consists of the shield of avalanches, erosion and rock fall and is mostly required in the Alps and Pre-Alps regions. Production has to be carried in such a way, that the forest area is maintained and harvest does not exceed stock growth, a sustainability criteria that was implemented in 1870 with the first forest law and still has its validity today. The welfare function includes biodiversity conservation, CO_2 reduction, recreation and environmental education. The Swiss forest law, thus, focuses on the utility of forests for humans.

Currently, the Swiss forest and wood economy is in a crisis (Schader and Messerli, 1995). In particular (i) only about 65% of the total wood growth is harvested in Swiss forest; (ii) wood prices have been constantly decreasing; (iii) most owners possess small areas of land, so that harvesting is inefficient[1]; (iv) sawmills and other wood processing industries consist to a large

[1] Public forest management enterprises, which are larger than private ones, have negative revenues (see Burri, and Sommerhalder, 2001 for Appenzell). In 2000, the subsidies for Swiss public enterprises were about 32% of total costs, the deficit still being 12% (BfS, 2002). The trend is negative, i.e., less income due to decreasing wood prices and higher costs due to increasing salaries.

extent of small enterprises, which are not flexible enough for processing wood if there is an increased demand; (v) no official wood quality criteria exist, which hinders selling wood on international markets; and (vi) the demand for local wood products is decreasing due to lower priced imported goods. In addition, sustainable forest management is to be implemented, accounting for forest ecosystem maintenance, biodiversity, protection, production, contribution to CO_2 reduction and other social services (e.g., recreation) (BUWAL, 1999; SAFE, 1998; SAEFL, 1998; SAEFL, 1999).

Within the energy and CO_2 debate, however, wood and thus forests play an important role (Streicher-Porte et al, 2002). One option discussed by the program EnergieSchweiz[2] (http://www.energie-schweiz.ch/bfe/de/energieschweiz/) and the Swiss Union for Wood Energy (www.vhe.ch) is to increase energy production from wood, which is a CO_2 neutral energy carrier. The rational is that energy production from wood could easily be increased without harming the forest or other wood uses. Increased regional use of wood would also decrease transport energy for imported wood and oil for heating and support regional development as the value added is kept within the region. Thus, improving regional wood flows would support transition towards a more sustainable development.

For achieving this goal a transition process is required that considers the current situation and within which strategies and measures are defined, which cope with the crisis and the changed and increased claims on forest and forest products. Transition processes have been prevalent in regional management and regional development (Ravetz, 2000; Scholz and Tietje, 2002; Wiek, in prep). Knieling (2000), Thierstein and Walser (2000), developed a typology for planning and managing transition processes in regions. Extensive experience was also gathered in ten large-scale studies at the Swiss Federal Institute of Technology (ETH Zürich) on urban and regional development. These studies are characterized by a process of mutual learning between science and practice with 50 to 100 participants from university and 100 to 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 on the transition process (see Mieg, 2000; Scholz et al. 1997; Scholz et al. 2002).

In this paper we discuss the contribution of material flux analysis (MFA) and agent analysis for transition processes. We postulate that the integration of these two methods provides important insights to a thorough system understanding as a prerequisite for a successful transition process. MFA has been applied to analyze and model materials balances of corporations and urban regions in industrialized countries (Baccini and Brunner, 1991; Baccini and Bader, 1996), to describe regional wood management of the Swiss lowlands (Müller, 1996; Müller, 1999) and to analyze the generation of waste in regional systems (Schwarzenbach et al., 1999). In developing countries, MFA has been applied to an urban region in Colombia to study the water balance (Binder, 1997) and the consumption of goods in regional systems (Binder, 2001).

[2] EnergieSchweiz is the new energy program of the Swiss Federal Government to implement the Swiss goals regarding climate change and sustainable energy use. It promotes renewable energies and the economical use of energy. Within the area of increasing energy out of wood, currently 20 projects are being supported.

Where as the analysis of agents and agent networks has been long established within sociology (Wassermann and Faust, 1994) their link to environmental models has only recently started to be a research topic (Axtell, 2002; Binder, 2002; Hirsch, 2002; to some extent, Spangenberg and Lorek, 2002). The identification and analysis of agents, who relate to the material flux analysis, seems a promising approach for studying problems in environmental sciences, as well as for developing strategies and measures for transition processes.

In this paper, we present an approach to integrate material flux analysis and agent analysis for supporting the transition process towards improved regional wood management in the region of Appenzell Ausserrhoden (AR), a Pre-Alps region in Switzerland. 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. We choose a region instead of a nation because according to Swiss law, the cantons are responsible for the implementation of sustainable forest management within the regions (Swiss Forest Law, Art. 16, Art. 20 – 25, Art. 27).

The questions discussed in this paper are:

1. What is the contribution of the integration of material flux analysis and agent analysis for supporting transition processes?
2. What are the main issues in regional wood-flow management in Appenzell Ausserrhoden?
3. Who are the key agents in the regional wood flow, what are their interaction patterns and the structure of regulation?

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

2 The study area

Appenzell Ausserrhoden (AR). With an area of 24,000 hectares AR is one of the four smallest cantons in Switzerland. A canton has an own constitution, lawmaking, and government and corresponds to a state. AR lies in the northeastern part of Switzerland. It is a pre-mountainous area with the altitude ranging between 400 m above sea level (shore of the 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 employees 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).

Historical development of the forest in AR. Originally AR was a completely forested area. After the Romans Imperia, Alemanni settled in AR in the 8th century. The settlements were characterized as sprawls, where each family had their own piece of land including a piece of forest. Already in the 18th century AR specialized in textile production and became one of the most industrialized areas in Europe while simultaneously keeping pasture farming. The high demand of workforce lead to an increasing population density followed by a higher demand of wood for buildings, furniture and firewood. In the late 18th century forests only remained along the riverbeds that are embedded in narrow canyons and on the mountain peaks[3]. At that time the average age of the trees had decreased to about 30 to 40 years. As a reaction in 1836, a community group founded an NGO, which bought grazing land and reforested it with spruce. This was the first movement towards forest protection. In 1877, Swiss government implemented the forest policy, that is, every canton had to employ a forest guard who had to ensure forest area maintenance. In addition, other energy carriers replaced wood. Thus, the pressure on forests decreased and the wooded area regenerated. It 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.

Forest structure. The current forest structure in AR is dominated by the decisions of the earlier centuries: The main tree type is imported spruce (55%), followed by fir (17%) and beech tree (15%). The relation between stock and age is skewed; old trees with age between 80 and 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 1). The same picture is reflected in the forest area by development stage. Only 15% of the forest area has young trees, whereas 60% are immature stand (Table 1).

[3] In 1850, only 16% of the area of the canton was covered with forests.

Table 1: *Forest structure in Appenzell Ausserrhoden in 1995*

Wood stock according to age groups		Forest area according to development stage	
0–40 years	4%	Young stand	4%
40–80 years	23%	Pole forest	11%
80–120 years	55%	Immature stand	60%
More than 120 years	3%	Mixed stand	21%
No defined age	15%	Not defined	4%

(Source: Ettlinger, 2001)

Property structure. The property structure can be also understood by the historical development of AR and it's forest management (Table 2). About 74% of the total forest is private property, whereas in Switzerland only 32% of the forest is private property (Brassel and Brändli, 1999). The largest part is conformed by private households (to a large extent farmers), who own in average tiny sites of 1.2 ha/cap and possess 67% of the total forest area, whereas corporations own about 7% of the forest area. 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).

Table 2: *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	4,983 ha	67.1 %
Communities	1,010 ha	13.6 %			
Other public organizations	576 ha	7.7 %			
Public Total	1,965 ha	26.4 %	Private Total	5,466 ha	73.6 %

(Source: Ettlinger, 2001)

Wood prices. During the last 10 years, net wood prices have constantly been decreasing. Hardwood prices have decreased from 1992 to 2001 by 15%, while prices for softwood nearly halved. (BfS and BUWAL, 2001). Prices for firewood and round timber also continually decreased reaching 88% and 78% of the 1992 price in 2001 respectively (Figure 1).

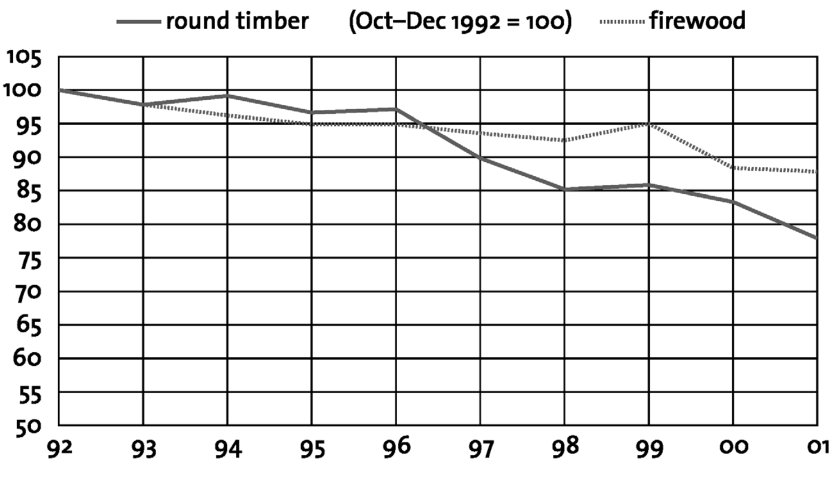


Figure 1: *Wood price index for round timber and firewood (Source: BFS & BUWAL, 2001)*

3 Material and Methods

3.1 The transition process

Three main steps characterize a transition process (Scholz and Wiek, 2002): (i) system understanding; (ii) goal formation; and (iii) backward planning (Figure 2).

In the first step a thorough understanding of the current system and its properties is attained. This includes the knowledge of material flows and the investigation of key agents and agent interactions (initial focal variables). This step is the prerequisite 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). The 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 involved agents identified in step 1. In this paper we look at the goal of improving regional wood flows as a step towards a more sustainable regional development.

The preceding two steps are the basis for planning strategies, measures and supervision criteria (step 3). In this step, the different interests in and between agents have to be negotiated. An important step in this negotiation is again a consensus building process. When the agents have agreed upon the measures and strategies to take, supervision criteria and instruments have to be designed for measuring the success of the strategies. This "controlling" process is most important and has to be planned from the very beginning and should cover the efficiency of the whole process (Ossadnik, 1996; Heitzer, 2001; Scholz, 2001).

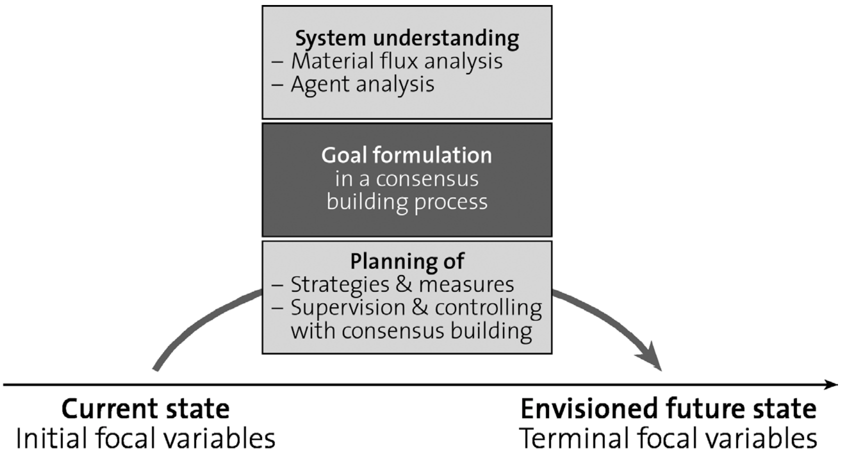


Figure 2: *The transition process departs from the current system and practice (initial focal variables) and leads through a complete negotiation and implementation process, which finally leads to a changed practice (terminal focal variables, see also Scholz and Wiek, 2002; Scholz and Tietje, 2002, p. 72,ff) (Source: adapted from Scholz and Wiek, 2002)*

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). MFA is based on the law of conservation of matter. A MFA model is defined by a system border, 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 different 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 fraction 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

Figure 3 shows the system analysis for wood flows in Appenzell Ausserrhoden. The system border is the political border of AR. The system is composed of six processes and 20 good-flows. In the forest, biomass is produced from CO_2. The forest owners decide to which extent the trees are harvested and which type of wood is produced. The direct outputs of the forest are: (i) round timber, which either is used by the regional saw-mills 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 wood. The specific use is not clear, however, we assume that the largest part is used as firewood.

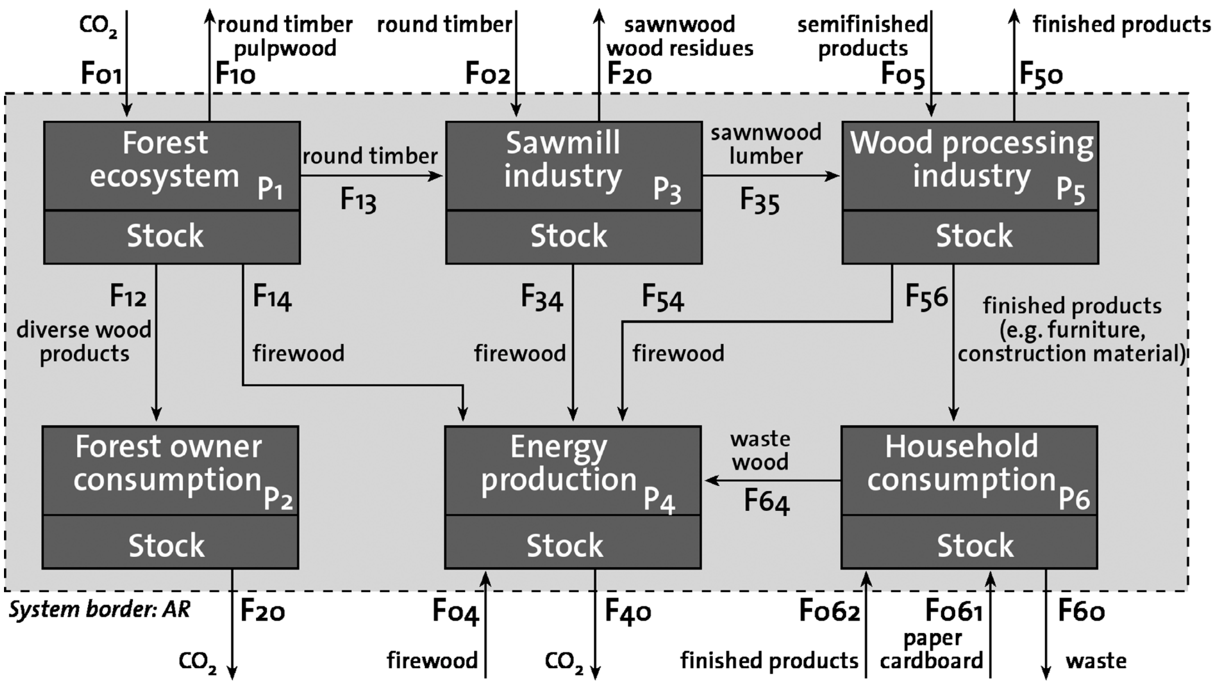


Figure 3: System analysis of the regional wood flow in Appenzell Ausserrhoden (Source: adapted from Hofer, 2001)

The mathematical formulation for a quasistationary model is given below[4]:

P_i, $i = 0,1,\ldots,6$, denote the different processes. The external processes P_o, i.e., the processes outside the system boarders, 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 system processes F_{ij} can be calculated by means of transfer coefficients (see above). Thus, any material flux of the inner system boarder is

$$F_{ij} = k_{ij} \sum_{m=0}^{6} F_{mi}, \; i = 1,\ldots,6. \qquad \text{(Eq. 1)}$$

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 running the mill as their 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 further processed in local wood processing industries and exported. Firewood is delivered to regional energy production, whereas wood residues are exported.

The wood processing industries import in addition to sawn wood also semi-finished products and produce and distribute furniture, products for self-assembly and construction material. According to expert interviews, in AR two types wood processing industries exist. First, the production of "3/4 – products", consisting of window frames, doors, parquet floor; and second, finished products such as, furniture, tiles, carpentry products. Paper and cardboard are not produced in AR.

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 wooden waste material and waste paper and cardboard. The process energy production consists of plants that produce energy from firewood, delivered from 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 Data sources and assumptions for the wood flow analysis

In the following the data sources and their error margins are described in detail for each process and the correspondent fluxes (Table 3). It was assumed that for all processes except forest, forest owners and private households, stock change is equal to 0[5]. We adapted the data for the reference year 1995.

Forest ecosystem. The data for forest stock, stock change and harvest was obtained and validated via two sources. First, the Swiss national forest inventory was performed in 1995

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

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

(Brassel and Brändli, 1999), and second, also in 1995, forest inventories were performed in more detail at level of the canton (Ettlinger, 2001). CO_2 input was calculated using total growth of soft and hardwood in the region, density of the wood types and the carbon content of wood.

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

Whereas:

$CO_2 / year$: 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 wood biomass (0.47, Pingoud, 1997)

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

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

Wood-processing industry. There are no regional statistics for the wood processing industries. The wood flows were estimated via two sources. On the one hand, the national statistics about the wood processing industries were utilized and adapted to the existing industries in the region. On the other hand, we validated these results with the average per capita demand of the products (BUWAL, 1998). Finally, we performed interviews with owners of wood processing 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).

Household consumption. As no regional consumption statistics exist, we assumed that household consumption in AR is consistent with Swiss average consumption (BUWAL, 1998)[6]. As no paper and cardboard industry exists in AR, all demand for paper and cardboard has to be 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). Households stock and stock growth were estimated according to Müller (1996). Stock growth is assumed to be 1% per year (Müller, 1999). The waste flux is thus equal total input minus stock growth. Interviews with regional experts suggest that 90% of waste wooden goods are exported, about 10% are used for energy production (Müller, 1999).

---

[6] For most regional MFA studies in Switzerland this assumption has been made (see Müller, 1996, 1999; Hug, 2002)

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.

Table 3: *Data sources and error margins for fluxes and stocks*

Flux/Stock	Formulae	Value	Error margin	Data source
Forest stock Stock change	P_1 dP_1/dt	3550,000 m³ + 42,000 m³/a	5% 5%	Brassel (1999) Ettlinger (2001)
Import: CO_2	F_{01}	200,200 t	5%	Equation 2
Diverse products	F_{12}	3,900 m³/a	7%	Ettlinger, (2001)
Round timber	F_{13}	17,400 m³/a	7%	Ettlinger (2001)
Firewood	F_{14}	2,300 m³/a	7%	Ettlinger (2001)
Export: round timber	F_{10}	4,400 m³/a	7%	Balance calculation
Forest owners stock Stock change	P_2 dP_2/dt	– 2,000 m³/a	– 20%	Not known Ass: $dP_2/dt = dP_6/dt$
Export: CO_2	F_{20}	1,400 m³/a	20%	Process balance
Sawmills stock Stock change	P_3 dP_3/dt	– 0	– 0	 Model assumption
Import: round timber	F_{03}	1,900 m³/a	25%	Interviews
Firewood	F_{34}	2,500 m³/a	10%	BfS & BUWAL (1999)
Sawnwood	F_{35}	9,400 m³/a	10%	BfS (1999)
Export: sawnwood, etc.	F_{30}	7,400 m³/a	25%	Interviews
Energy prod. Total firewood input	P_4 dP_4/dt	– – 14,100 m³/a	– – 10%	 Model assumption BfS (1999)
Import: firewood	F_{04}	5,800 m³/a	5%	Process balance
Export: CO_2	F_{40}	11,100 m³/a	5%	Equation 2
Wood processing Stock change	P_5 dP_5/dt	– 0	– 0	 Model assumption
Total production		14,600 m³/a	10%	BfS & BUWAL (1999)
Import: semifinished	F_{05}	6,800 m³/a	25%	Interviews
Firewood (residues)	F_{54}	3,400 m³/a	10%	BfS & BUWAL (1999)
Finished products	F_{56}	6,400 m³/a	20%	BfS & BUWAL (1999) interviews
Export: products,	F_{50}	6,400 m³/a	25%	Interviews
Household stock (M_6) dM_6/dt	P_6 dP_6/dt	 + 1% per a	30% 50%	Müller (1996, 1999) Müller (1996, 1999)
Waste wood	F_{64}	1,2000 m³/a	30%	Müller, (1996, 1999)
Import: paper, cardboard	F_{061}	15,800 m³/a	10%	BUWAL (1998)
Import: products	F_{062}	6,400 m³/a	10%	BUWAL (1998)
Export: waste, incl. Paper	F_{60}	28,600 m³/a	30%	Process balance

3.3 Agent analysis

Agent and agent network analysis are well established within sociology. Several types of agent analyses exist, which range from qualitative analysis to quantitative, statistical analysis (Esser, 1993; Wasserman and Faust, 1994). In this paper, we focus on a qualitative approach linked to a graphical representation. The structure of regulation among the agents was determined and classified according to the structural theory of Giddens (1979). The structural theory of Giddens has been applied mostly in the field of organizational theory. Specifically the link between innovation, technological change and organizational changes has been analyzed using this framework. In both cases, it was shown that the theory of structuration allowed for a deeper understanding of the relationship between organization and technological change or innovation. It provided insights about limits and opportunities of human choice as well as about the constraint and enabling aspects of organizational structure (Barley, 1990; Orlikowski, 1992; Edwards, 2000; Jones, Edwards, and Beckinsale, 2000). Hirsch et al, (2002) combined the theory of structuration of Giddens with life cycle analyses. Binder (2002) applied for the first time the structuration theory to developing countries to identify options and restrictions within the consumption of interiors of different social strata in Tunja, Colombia.

***Table 4**: 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 discussion (Total 13 persons)	Forest owners Sawmill owners Wood processing industries Consumers	Main problems of the wood chain Main influences on the wood chain Relevance of national programs (e.g., wood certification, sustainable forestry, EnergieSchweiz)
Expert interviews (face to face)	Forestry service of the Canton Zürich (Chief for forestry planning) Forestry service of Canton AR (Chief of forestry service) Professor for Forest Policy and Forest Economics, ETHZ	Results from wood flow analysis Results from agent analysis Structure of regulation Strategies for improving regional wood management

In this paper, the structure of regulation was divided into economics or market related interactions (allocative resources), legislation (legitimation), and cultural values (signification). It has to be noted that the agent analysis relates directly to the main 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, a sample of these agents was interviewed with standardized interviews concerning their interaction with other agents within the wood chain (ratio of imported vs. regionally produced wood, ratio of exported vs. wooden goods sold in the region). These data were also utilized for the wood flow analysis (Table 3). In a roundtable discussion (Lang, 2002), with forest owners, sawmill owners, wood processing industries and consumers, first types of interactions and regulation structures were identified. Based on these data, third, an agent an analysis was set up, which was thoroughly discussed with experts from politics and forestry research (Mieg and Brunner, 2001). The agent analysis was revisited and complemented. In addition, first possible strategies were discussed (Table 4).

4 Results

4.1 Wood flow analysis

Figure 4 presents the wood flow in AR for the year 1995. The forest has a wood stock of about 3.55 million m^3, which corresponds to 470 m^3/ha. Currently, each year the stock grows by 70,000 m^3, whereof only 28,000 m^3 (i.e., 40 %) are utilized (Ettlinger, 2001). That is, the forest is underutilized. A comparison to Swiss average forest stock shows, that the forest stock in AR is about 100 m^3/ha higher than the Swiss average. The public forest is more intensely managed than the private forest. Whereas in public forests from 1996 to 2001[7] 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 average of 4.6 m^3/ha for AR (Ettlinger, 2002). This harvest rate is 2/3 the one obtained in Switzerland for the period of 1985 to 1995 and nearly half the one of the pre-Alps 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. The exported wood is to a large extent pulpwood for paper production.

Sawmills process mostly locally grown wood (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.

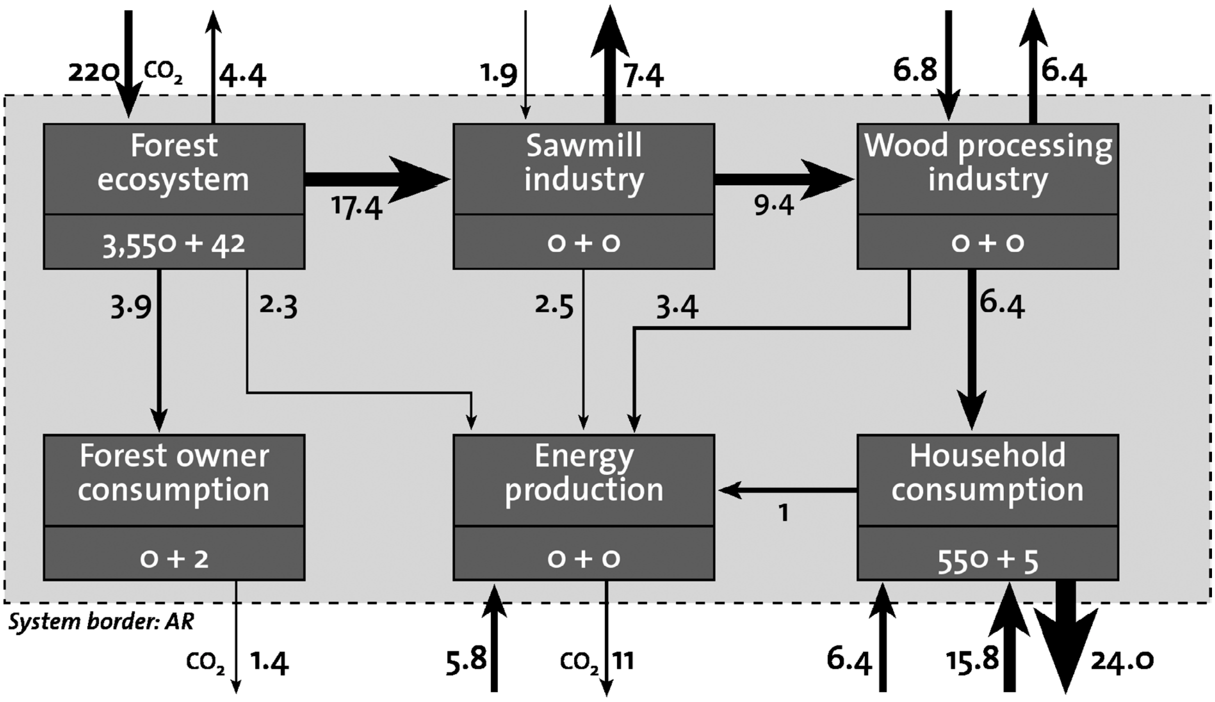


Figure 4: Wood flows in Appenzell Ausserrhoden for the year 1995 (Source: adapted from Hofer, 2001)

7 Data from the period 1985 to 1995 was not available, but according to Ettlinger (2002) the harvest rates were even lower then the ones in the period from 1996 to 2001.

The wood processing industries use 9,400 m^3/year (58%) of the regional wood, the rest are imported semi-finished goods, or other wood types (total 6,800 m^3/year). The products of the wood processing industries are used for construction (63%) and for "3/4 - products" and furniture (37%). Within AR, 6,400 m^3/year (40%) of their products are consumed; the same amount is exported and 3,400 m^3/year (20%) are wood residues. Within production, the waste share is highest for furniture and parquet manufacture (40 to 50%) and lowest for carpentry and tiles fabrication (10%). The wood residues are used for energy production.

The total final demand of households is presented in Table 5. Theoretically, the wood processing industries could cover about 50% of the demanded wood products (including firewood). However, the amount of regional wooden goods consumed is only 34% (firewood included). The rest, mainly paper, cardboard and packaging material, as well as some furniture and construction materials are imported. Used paper, cardboard and old wooden products are exported for recycling or for incineration as no such facilities are available in AR. If the total wood consumption in AR is compared to the stock growth per year in the forests, one can see that regional resources could easily cover the total demand.

***Table 5**: Final demand of wood products in Switzerland and AR in 1995*

Product	Percentage [1]	Consumed in AR (1000 m^3/year)[1]	Produced in AR
Energy	33%	14.1	8.2
Paper and cardboard	29%	12.5	No
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%

1: Calculations based on BUWAL (1998)
(Stock in 1000 m^3 wood flows in 1000 m^3 wood/year, 1000t CO_2).

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

Increasing wood stock in forests

The forests in AR are underutilized despite considerable imports of wood and wood products into the region. The imported amount of wood of 42,000 m^3 corresponds to the unutilized stock growth of forests in AR. About 40% (15,800 m^3) of these imports (mainly paper and cardboard) cannot be produced in the region, due to the large infrastructure required. However, 60% of the imports could easily be covered by regional wood sources, if the forest were managed adequately.

Import of wood by wood processing industries (40%) and sawmills (10%)

Wood processing industries import about 40% of their wood requirements. To a large extent this wood could be supplied by own regional sources. In addition, they produce only about 50% of the products of final demand. Interesting is the fact that family and small wood processing industries use mostly regionally produced wood and sell their products within the region. Industries with more than 10 employees import most of the used wood and export their products. The wood imported is usually from the Nordic countries (e.g., Sweden).

Import of wood for energy production

The regional energy demand is currently not being completely satisfied by regional wood sources. Energy production uses mostly waste or rest wood from the production industries and some waste wood of household consumption. Given the fallow resources in the forests, the current energy demand (wood energy) could be covered. There would also be a potential for enhancing energy production beyond the current demand. This might be a strategy to follow, as with the Kyoto Protocol Switzerland committed itself to reduce CO_2 emissions. For doing so, Swiss government is likely to increase the price for fossil fuels (http://www.energie-schweiz.ch/bfe/de/energieschweiz/). For the still existing regional textile industry, where energy makes up for 40% of the production costs, a switch to regionally produced wood energy might be an adequate option.

4.2 Agent analysis

4.2.1 Key agents

The key agents are defined as stakeholders, who determine or regulate the three issues which resulted from the wood flow analysis, namely (1) increasing wood stock in forests; (2) import of wood by wood processing industries and sawmills; and (3) import of wood for energy production (Table 6).

Issues	Key agents
Increasing wood stock in forests	Forest owners (D) Cantonal and federal government (I) Consumers & construction industries (I)
Import of wood by wood processing industries and sawmills	Wood processing industries (D) Sawmill owners (I) Consumers & 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 & construction industries (I) Textile industry (I)

D: direct influence, I: indirect influence

***Table 6**: Key agents determining the main issues in regional wood management (Source: Own investigation)*

Forest owners directly influence increasing wood stock in forests. Cantonal and federal government play an important regulative role given their possibilities of legislation and subsidies. Agents involved in demand, such as consumers and construction industry, have an indirect effect on forest stock. Import of wood by wood processing industries and sawmills is directly determined by wood processing industries and sawmills themselves. They are influenced by the demand of consumers and construction industries and the potential supply of wood from forests within the region. Import of wood for energy production is related to the action of energy industries. It is influenced by the demand of consumers, construction and textile industries for wood energy. In addition, it requires that agents such as forest owners and wood processing industries can deliver sufficient regional wood (-residues) to satisfy the local demand.

4.2.2 Agent interaction and structure of regulation

Figure 5 shows the main interactions (regarding the demand of wood and wood products) among the key agents as well as the structure of regulation. Three structures of regulation were identified in the analysis: market mechanisms (related to allocative resources), legislation (related to legitimation), and cultural values (related to signification). The agent's interactions take place along these structures of regulation.

Increasing wood stock in forests. Forest owners are influenced by the three structures of regulation mentioned above. Market mechanisms reflect the demand by consumers as well as the competition of foreign products through prices for a certain wood type and quality. Currently, this is the strongest structural element affecting forest owners. Low wood prices for fir, which are dominant and native tree species in AR, make it difficult to obtain positive revenue for wood. In addition, old trees dominate the forest structure (Table 1) and only a few sawmills have the necessary machinery for sawing thick trees. The demand of consumers and construction industries for other wood types cannot be satisfied because these tree types cannot be grown in this region and the forest structure cannot rapidly be adapted to changes in demand. In addition, demand changes might occur in time ranges of 10 to 20 years, whereas trees grow in time periods of 50 to 100 years. Therefore, it is difficult for forest owners to adapt to changes in demand for different wood types. That is, the structure of demand and the potential supply of wood are not in agreement with each other.

Federal and cantonal legislation provide some baselines on how to manage the forest. They include legislation about maximal harvest and prohibition of clear cutting. Forest owners are not obliged to manage their forest as long as the protection function of the forest is guaranteed and no other type of forest is harmed. Owners with more than 15 ha of forest have to elaborate a forest management plan (AR Cantonal Forest Law, Art. 19b1). Owners of smaller plots are exempt if they harvest maximal 10 m^3/ha and year and are located outside a zone designated for protection. As 67% of the forest area is privately owned (with an average area of 1.2ha/owner), it is difficult to consolidate a common forest management strategy. In addition, legislation determines that the cantons should provide counseling to forest owners concerning the management of their forests. This could play an important role in implementing new management strategies.

Cultural values, such as traditions and business relations play a large role in the agent system depicted above. Possessing a small piece of forest has a high tradition value for forest owners and thus, they are not willing to, for example, sell their forest. Another important factor are informal and formal contracts between forest owners and wood processing industries, sawmill owners, or energy industries. These contracts played a large role when wood was scarce for ensuring a minimum supply to wood processing industries. Today they might be useful structures for ensuring a minimum market for forest owners. Even tough in some regions (e.g., Kanton Zürich) these contracts still exist, they have lost their relevance (Hess, personal communications, 2002). In AR, interviews with wood processing industries showed that mostly small family enterprises buy most of their wood from local forest owners. Larger enterprises, however, import most of their wood.

Wood import of by wood processing industries and sawmills is regulated by market mechanisms and cultural values. Concerning the first, wood processing industries are among the forest owners as suppliers and consumers and construction industry as demand. If they cannot fulfill the local demand with local resources or if the local resources are too expensive they will choose to import cheaper or higher quality wood. Here the role and the importance of the cultural values of the consumers becomes apparent: Demand changes depending on their lifestyle and the valuation of local versus imported wood are relevant parameters influencing the regional wood flow. According to interviews and roundtable discussions with seven sawmill owners and statements of a board of six cantonal experts (Lang, 2002), currently there is a tendency to prefer harder and better wood quality from the Scandinavian countries. This is due to the fact that architects and customers doubt on the quality of Swiss wood. Another aspect is the increasing preference for semi-finished goods (or goods for self-assembly). These goods require wood from young trees that is of weaker quality of wood. Now the conflict for forest owners becomes apparent if they want to be able to supply the local wood industry: while for construction and certain type of uses hard wood is needed, which requires a certain type of trees and old trees, for producing semi-finished goods, weak wood quality from young trees is needed.

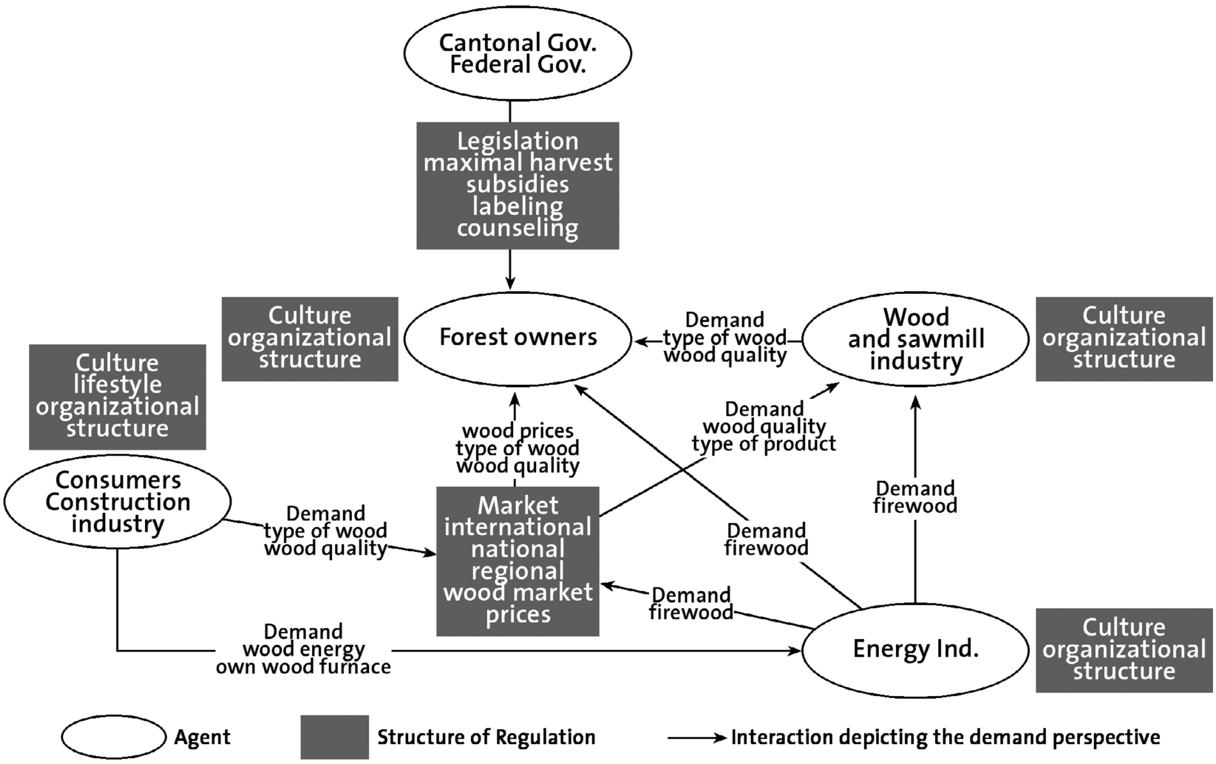


Figure 5: *Agents and their type of interaction and regulation (Source: Own investigation)*

Import of wood for energy production. Energy production industries are also influenced by market mechanisms, cultural values and legislation. These industries react to the demand of consumers, construction and textile industries. Here, the federal government could also play an important role. For example, the Swiss Government might decide to subsidize wood furnaces for implementing the goal stated in the EnergieSchweiz program (http://www.energie-schweiz.ch/bfe/de/energieschweiz/), to increase the use of wood for energy production (Lang, 2002). One additional condition to this subsidy could be to utilize locally produced wood, where possible. Other mechanisms are market mechanisms, such as increasing the price of oil for heating. This could also increase the demand for wood energy in, e.g., textile industries. Life-style changes towards "cleaner energies" could also lead to increased use of wood as energy carrier.

4.3 Proposed next steps in the transition process

The integration of wood flow analysis and agent analysis revealed the main issues, the related agents, and the corresponding structure of regulation. It became clear that the goals and motivations of the different agents have to be consolidated if a change and optimization in the regional wood flow wants to be achieved. The next steps to take are consensus building (Cormick, 1996), design of strategies and measures with agent-related roles (Laws et al., 2001), as well as the design of supervision and controlling tools (Scholz, 2001). We suggest, that these steps are institutionally framed. This is particularly useful if the implementation of strategies wants to be ensured. 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 for a local initiative among key players to promote product development and distributions and thus has the potential to support the process to improve 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 wooden products better be 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 wood 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 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
- Possibility of regional production of semi-finished products

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

In transition processes, system analysis and system understanding are all stated to be important and relevant for the transition process (Knieling, 2000; Ravetz, 2000; Scholz and Wiek, 2002; Scholz and Tietje, 2002). The goals that a good system analysis has to fulfill are:

- Provide a thorough system understanding, which gives insight into the main problems and areas of conflict within the region or in our case regarding the regional wood flows.
- Provide a basis for strategy building within a consensus building process, including the integration of the relevant stakeholders.

The integration of MFA with agent analysis provides first a quantitative analysis of the wood flow within the region. This allows for identifying the main issues regarding regional wood management. By linking the key agents to the wood flows, we are able to identify the stakeholders determining these issues as well as the areas of conflict or disagreement. This information is a prerequisite for an effective consensus building process. That is, strategies can be discussed and their implication on the wood flow estimated. Knowing the structure of the regulation, the restrictions for the implementation of these measures can be identified and discussed in the consensus building process. The graphical representation allows for an abstraction from the own enterprise and provides thus, a neutral, but quantitative foundation for the discussions. Measures can to be set up, which are of quantitative manner, facilitating the controlling process.

Obviously, the selected methods have some drawbacks: In the quantitative analysis, issues such as forest beauty, are not integrated; these have to be brought forward by the stakeholders during the consensus building process. In addition, we consider that the strategies discussed have to be thoroughly evaluated, including in particular economic and social parameters. In general, regarding environmental problems, the integration of MFA and agent analysis provides a basis that goes well beyond a purely environmental analysis, facilitating so strategy and consensus building among the stakeholders.

6 Conclusions

The paper showed that the integration of material flux analysis and agent analysis is a prerequisite 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 is the first step for a transition process, because (i) quantitative measures can be visualized and controlling mechanisms can be set up; (ii) structural mechanisms that impede changing the regional wood flows can be identified and strategies defined; and (iii) conflicts between the agents and the regional goals become apparent and can, thus, be solved.

In AR the main issues and involved agents in the regional wood management are:

1. **Increasing wood stock in forests.** The forest in AR is currently underutilized, i.e., wood harvest could be increased by at least a factor of 2. The current cost structure does not create any incentives for harvesting more wood. Forest owners decisions are determined by prices, but also by the rapid varying demand of wood processing industries and consumers. While demand changes in time ranges of 10 to 20 years, forest management has to consider time ranges of 50 to 100 years.
2. **Wood import of by wood processing industries and sawmills.** Currently, only 50% of the regional demand is satisfied by regional wood supply. Mostly demand for semi-finished goods and for specific wood types cannot be satisfied. As wood processing industries are in between demand and supply they could play the role of catalysts for the transition process towards improved regional wood flows.
3. **Import of wood for energy production.** Energy production out of wood might easily be increased, if more wood is used in the wood processing industries (more waste wood) or if the forest is managed properly. If the potential is utilized by regional industries, i.e., textile industries, not only the forest would be managed better, but also the overall CO_2 emissions could be reduced. In this case formal contracts could ensure a constant regional supply and, for forest owners, a minimum market.

The main issue where consensus building is needed and strategies and measures have to be designed is the alignment of supply and demand. An option might be to rethink formal contracts for regional wood supply in a defined quality in order to ensure forest owners a market share and wood processing industries and consumers an agreed upon quality.

Acknowledgements

The authors thank Olaf Tietje, Michael Stauffacher, Willi Zimmermann, Thomas Köllner and Daniel Lang for their critical comments, Peter Ettlinger and Hermann Hess for their support, Michel Jenny and Christian Danneker for research assistance, and Sandro Bösch for support in the design of the paper.

References

Axtell, R. L., Andrews, C. J., & Small, M. J. (2002). Agent-based modeling and industrial ecology. *Journal of Industrial Ecology, 5*, 10-14.

Baccini, P., & Bader, H.-P. (1996). *Regionaler Stoffhaushalt. Erfassung, Bewertung und Steuerung [Regional material budget. Registration, evaluation and control]*. Heidelberg, Germany: Spektrum.

Baccini, P., & Brunner, P. H. (1991). *Metabolism of the anthroposphere*. Berlin, Germany: Springer.

BfS, & BUWAL. (1999). *Holzverarbeitung in der Schweiz 1996 - Studien über den Holzfluss 1991 - 1996 [Wood processing in Switzerland 1996 - studies on wood flow 1991-1996]*. Bern, Switzerland: Bundesamt für Statistik und Bundesamt für Umwelt, Wald und Landschaft.

BfS, & BUWAL. (2001). *Wald und Holz: Jahrbuch 2001 [Forest and wood: Yearbook 2001]*. Bern, Switzerland: Bundesamt für Statistik und Bundesamt für Umwelt, Wald und Landschaft.

Binder, C., Bader, H.-P., Scheidegger, R., & Baccini, P. (2001). Dynamic models for managing durables using a stratified approach: the case of Tunja, Colombia. *Ecological Economics, 38*, 191-207.

Binder, C., Schertenleib, R., Diaz, J., & Baccini, P. (1997). Regional water balance as a tool for water management in developing countries. *Water Resource Management, 13*, 5-20.

Binder, C. R. (2002). *Integrating material flux analysis and structural agent analysis: The case of interiors in Tunja, Colombia*. Zürich, Switzerland: Natural and Social Science Interface.

Brassel, P., & Brändli, U.-B. (1999). *Schweizerisches Landesforstinventar. Ergebnisse der Zweitaufnahme 1993-1995 [Swiss forest inventary. Results of the second inventory 1993-1995]*. Bern, Switzerland: Haupt.

Brunswik, E. (1950). *The conceptual framework of psychology*. Chicago: University of Chicago Press.

Burri, R., & Sommerhalder, R. (2001). Betriebsergebnisse 1992 bis 2000 der öffentlichen Forstbetriebe im Kanton Appenzell Ausserrhoden [Operational results 1992 to 2000 of the public forestry in the Kanton Appenzell Ausserrhoden]. *Schweizerische Zeitung für Forstwesen, 152*, 270-281.

BUWAL. (1998). *Endverbrauch des Holzes in der Schweiz 1996 [End consumption of wood in Switzerland 1996]* (Umweltmaterialien 94 Holz). Bern, Switzerland: Bundesamt für Umwelt, Wald und Landschaft.

BUWAL. (1999). *Nationale Standards für die Waldzertifizierung in der Schweiz. Stand Juni, 1999 [National standards for forest certification in Switzerland. As of June 1999]*. Bern: Bundesamt für Statistik und Bundesamt für Umwelt, Wald und Landschaft.

Cormick, G. (1996). *Building consensus for a sustainable future: putting principles into practice* (National round table series on sustainable development). Ottawa, Canada: National round table on the environment and the economy.

Deer, & Gugger (Eds.). (2002). *Der Kanton Appenzell Ausserrhoden in Zahlen [The Kanton Appenzell Ausserrhoden in numbers]*. St. Gallen, Switzerland: Deer and Gugger.

Esser, H. (1993). *Soziologie: Allgemeine Grundlagen [Sociology: General basics]*. Frankfurt am Main, Germany: Campus.

Ettlinger, P. (2001). Entwicklung und Behandlung der Wälder in Appenzell Ausserrhoden [Development and treatment of forests in Appenzell Ausserrhoden]. *Schweizerische Zeitung für Forstwesen, 152*, 1-7.

Giddens, A. (1979). *Central problems in social theory: action, structure and contradiction in social analysis*. London: MacMillan.

Heitzer, A. (2000). Strategien und Konzepte der Erfolgskontrolle [Strategies and concepts of success control]. In R. W. Scholz (Ed.), *Erfolgskontrolle von Umweltmassnahmen*. Heidelberg, Germany: Springer.

Hirsch Hadorn, G., Wölfling Kast, S., & Maier, S. (2002). Restrictions and options: a heuristic tool to integrate knowledge for strategies towards a sustainable development. *International Journal for Sustainable Development, 9*, 193-207.

Hug, F. (2002). *Ressourcenhaushalt alpiner Regionen und deren physiologische Interaktionen mit den Tiefländern im Kontext einer nachhaltigen Entwicklung [Resource balance of alpine regions and their physiological interactions with lowlands within the context of sustainable development]*. Unpublished Diss. ETH Nr. 14540, Eidgenössische Technishce Hochschule Zürich, Zürich, Switzerland.

Johnson-Laird, P. N. (1983). *Mental models towards a cognitive science of language, inference, and consciousness*. Cambridge, MA: Cambridge University Press.

Jungermann, H., Pfister, H.-R., & Fischer, K. (1998). *Die Psychologie der Entscheidung: Eine Einführung [Psychology of decision. An introduction]*. Heidelberg, Germany: Spektrum.

Kleijn, R., Huele, R., & van der Voet, E. (2000). Dynamic substance flow analysis: the delaying mechanism of stocks, with the case of PVC in Sweden. *Ecological Economics*(32), 241-254.

Knieling, J. (2000). *Leitbildprozesse und Regionalmanagement. Ein Beitrag zur Weiterentwicklung des Instrumentariums der Raumordnungspolitik [Model processes and regional management. A contribution to the development of the instrumentary of environmental planning policy]*. Frankfurt am Main, Germany: Lang.

Lang, D. (2002). *Discussion forum of sawmill owners in Appenzell Ausserrhoden*.Unpublished manuscript, Zürich, Switzerland.

Laws, D., Susskind, L. E., Abrams, J., Anderson, J. R., Chapman, D., Rubenstein, E., & Vadgama, J. (2001). *Public entrepreneurship networks. The environmental technology and public policy program*. Boston: Massachusetts Institue of Technology.

Mieg, H. A. (2000). University-based projects for local sustainable development: Designing expert roles and collective reasoning. *International Journal of Sustainability in Higher Education, 1*, 67-82.

Mieg, H. A., & Brunner, B. (2001). *Experteninterviews [Expert interviews]* (MUB Working Paper 6). Zürich, Switzerland: Professur Mensch-Umwelt-Beziehungen, Swiss Federal Institute of Technology.

Müller, D. (1996). Szenarien zur nachhaltigen regionalen Holzbewirtschaftung [Scenarios for sustainable regional wood management]. *Schweizerische Zeitschrift für Forstwesen, 147*(11), 873-885.

Müller, D. B. (1999). *Modellierung, Simulation und Bewertung des regionalen Holzhaushaltes [Modelling, simuation and evaluation of regional wood management]*. Unpublished Doctoral, Eidgenössische Technische Hochschule Zürich, Zürich, Switzerland.

Ossadnik, W. (1996). *Controlling*. München, Germany: Oldenbourg.

Pingoud, K., & Lehtilä, A. (1997). Role of forest sector and bioenergy in limiting the carbon emissions of Finland. *Biomass and Bioenergy, 13*, 413-420.

Ravetz, J. R. (2000). *City-Region 2020. Integrated planning for a sustainable environment*. London: Earthscan.

BUWAL. (1998). *Criteria and indicators for sustainable forest management*. Bern, Switzerland: Bundesamt für Umwelt, Wald und Landschaft.

BUWAL. (1999). *Sustainability assessment of swiss forest policy* (Environmental Documentation 120). Bern, Switzerland: Bundesamt für Umwelt, Wald und Landschaft.

Schader, S., & Messerli, P. (1995). *Regionalwirtschaftliche und ökologische Effekte der Wald- und Holzwirtschaft [Regional economical and ecological effects of forest and wood management]* (Umweltmaterialien 35. Holz). Bern, Switzerland: Bundesamt für Umwelt, Wald und Landschaft.

Scholz, R. W. (1987). *Cognitive strategies in stochastic thinking*. Dordrecht, The Netherlands: Reidel.

Scholz, R. W. (2000). Mutual learning as a basic principle of transdisciplinarity. In R. W. Scholz & R. Häberli & A. Bill & M. Welti (Eds.), *Transdisciplinarity: Joint problem-solving among science, technology and society. Workbook II: Mutual learning sessions* (pp. 13-17). Zürich, Switzerland: Haffman.

Scholz, R. W. (2001). *Erfolgskontrolle von Umweltmassnahmen [Evaluation of goal attainment for environmental measures]*. Heidelberg, Germany: Springer.

Scholz, R. W., Bösch, S., Mieg, H. A., & Stünzi, J. (1997). *Zentrum Zürich Nord: Stadt im Aufbruch. Bausteine für eine nachhaltige Stadtentwicklung. UNS-Fallstudie 1996 [City Center Zurich North - A city on the move. Components for a sustainable urban development. ETH-UNS Case Study 1996]*. Zürich, Switzerland: vdf.

Scholz, R. W., Stauffacher, M., Boesch, S., & Wiek, A. (Eds.). (2002). *Landschaftsnutzung fuer die Zukunft: der Fall Appenzell Ausserrhoden. ETH-UNS Fallstudie 2001 [Utilisation of landscape for the future: The case of Appenzell Ausserrhoden. ETH-UNS Case Study 2001]*. Zürich, Switzerland: Rueegger und Pabst.

Scholz, R. W., & Tietje, O. (2002). *Embedded case study methods: Integrating quantitative and qualitative knowledge*. Thousand Oaks, CA: Sage.

Scholz, R. W., & Wiek, A. (2002). Transdisziplinäre Fallstudien zur Regionalentwicklung [Transdisciplinary case studies in regional development]. In A. Gerber & W. Konold (Eds.), *Nachhaltige Regionalentwicklung durch Kooperation - Wissenschaft und Praxis im Dialog* (Vol. 29). Freiburg, Germany: Albert-Ludwigs-Universität Freiburg.

Schwarzenbach, R. C., Heitzer, A., Stäubli, B., Grossmann, B., & Scholz, R. W. (1999). A regional perspective on contaminated site remediation - Fate of materials and pollutants. *Environmental Science and Technology, 33*, 2305-2310.

Seintsch, B., & Becker, M. (2002). *Umweltverträgliche Regionalentwicklung durch Aktivierung endogener forst- und holzwirtschaftlicher Potentiale [Environmentally sound regional development through activation of endogene forest and wook management potentials]*. Freiburg i. Br., Germany: Universität Freiburg.

Spangenberg, J. H., & Lorek, S. (2002). Environmentally sustainable household consumption: from aggergate environmental pressures to priority fields of action. *Ecological Economics, 43*, 127-140.

Streicher-Porte, M., Einem, N. v., & Walter, A. (2002). *Kann der Zürichbergwald unter den gegebenen Nutzungsinteressen substanziell zum Klimaschutz beitragen? [Can the forest of Zürichberg under the given stakeholder interests contribute significantly to climate protection?]* (Report). Zürich, Switzerland: Natural and Social Science Interface, Swiss Federal Institute of Technology.

Thierstein, A., & Walser, M. (2000). *Die nachhaltige Region. Ein Handlungsmodell. [The sustainable region. A model of action]*. Bern, Switzerland: Haupt.

van der Voet, E., Kleijn, R., Huele, R., Ishikawa, M., Verkuijlen, E. (2002). Predicting future emissions based on characteristics of stocks. *Ecological Economics, 41*, 223-234.

Wasserman, S., & Faust, K. (1994). *Social network analysis: methods and applications*. Cambridge, MA: Cambridge University Press.

Wiek, A. (in prep.). *Integrated management of regional transition processes. Case studies in Switzerland (Basel and Appenzell Ausserrhoden) In Preparation*.

ETH-UNS Working Papers

■ UNS-Working Paper 1 (Out of Print)

Scholz, R.W. (1994). **Muss man den Formalismus beherrschen, um die Formalisten zu schlagen?** Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

(Published as: Scholz, R.W. (1998). Umweltforschung zwischen Formalwissenschaft und Verständnis: Muss man den Formalismus beherrschen, um die Formalisten zu schlagen? [Environmental research between formal science and comprehension: is command of the formalism necessary for beating the formalists?] In A. Daschkeit & W. Schröder (Eds.), Umweltforschung quergedacht: Perspektiven integrativer Umweltforschung und -lehre [Environmental research thought laterally: perspectives on integrating environmental research and teaching] (pp. 309–328). Berlin: Springer.)

■ UNS-Working Paper 2 (Out of Print)

UNS (1994). **Lehrstuhlbeschreibung Umweltnatur- und Umweltsozialwissenschaften (UNS). Fallstudie, Forschung und Berufspraxis**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

■ UNS-Working Paper 3

Mieg, H.A. (1994). **Die Expertenrolle**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

■ UNS-Working Paper 4

Heitzer, A. & Scholz, R.W. (1994). **Monitoring and evaluating the efficacy of bioremediation – a conceptual framework**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

■ UNS-Working Paper 5 (Out of Print)

Scholz, R.W., Weber, O., & Michalik, G. (1995). **Ökologische Risiken im Firmenkreditgeschäft**. Zürich: ETH-Zürich, Umweltnatur- und Umweltsozialwissenschaften.

(Published as: Scholz, R.W., Weber, O., & Michalik, G. (1995). Ökologische Risiken im Firmenkreditgeschäft. [Ecological risks in loans to enterprises] In Overlack-Kosel, D., Scholz, R.W., Erichsen, S., Schmitz, K. W., and Urban, G. (Eds.), Kreditrisiken aus Umweltrisiken [Loan risks due to environmental risks (pp. 1–49). Bonn: Economica.)

■ UNS-Working Paper 6 (Out of Print)

Scholz, R.W., Heitzer, A., May, T., Nothbaum, N., Stünzi, J., & Tietje, O. (1995). **Datenqualität und Risikoanalysen – Das Risikohandlungsmodell zur Altlastenbearbeitung**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

(Published as: Scholz, R.W., Heitzer, A., May, T. W., Nothbaum, N. Stünzi, J., & Tietje, O. (1996). Datenqualität und Risikoanalysen: Das Risikohandlungsmodell zur Altlastenbearbeitung. [Data quality and risk analyses. The Risk Action Model of soil remediation] In S. Schulte-Hostede, R. Freitag, A. Kettrup, and W. Fresenius (Eds.), Altlasten-Bewertung: Datenanalyse und Gefahrenbewertung [Evaluation of soil remediation cases: analysis of data and evaluation of risks] (pp. 1–29). Landsberg: Ecomed.)

■ UNS-Working Paper 7 (Out of Print)

Scholz, R.W., Mieg, A.H., & Weber, O. (1995). **Mastering the complexity of environmental problem solving by case study approach**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

(Published as: Scholz, R.W., Mieg, H.A., & Weber, O. (1997). Mastering the complexity of environmental problem solving with the case study approach. Psychologische Beiträge, [Contributions to Psychology] 39, 169–186.)

■ UNS-Working Paper 8 (Out of Print)

Tietje, O. & Scholz, R.W. (1995). **Wahrscheinlichkeitskonzepte und Umweltsysteme**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

(Published as: Tietje, O. & Scholz, R.W. (1996). Wahrscheinlichkeitskonzepte und Umweltsysteme. [Concepts of probability and environmental systems] In A. Gheorghe & H. Seiler (Eds.), Was ist Wahrscheinlichkeit? Die Bedeutung der Wahrscheinlichkeit beim Umgang mit technischen Risiken [What is probability? The meaning of probability in the case of technical risks] (pp. 31–49). Zürich: vdf.)

■ UNS-Working Paper 9 (Out of Print)

Scholz, R.W. (1995). **Grenzwert und Risiko: Probleme der Wahrnehmung und des Handelns**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

(Published as: Scholz, R.W. (1996). Grenzwerte und Risiko: Probleme der Wahrnehmung und des Handelns. [Standards and risks: Problems of cognition and of action] In A. Grohmann & G. Reinicke (Eds.), Transparenz und Akzeptanz von Grenzwerten am Beispiel des Trinkwassers [Transparency in the setting of standards and their acceptance in the case of drinking water] (pp. 5–19). Berlin: Erich Schmidt Verlag.)

■ UNS-Working Paper 10 (Out of Print)

Weber, O. (1995). **Vom kognitiven Ungetüm bis zur Unverständlichkeit: Zwei Beispiele für Schwierigkeiten im Umgang mit Grenzwerten**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

(Published as: Weber, O. (1996). Vom kognitiven Ungetüm bis zur Unverständlichkeit: zwei Beispiele für Schwierigkeiten im Umgang mit Grenzwerten. [From cognitive monsters to incomprehensibility: two examples of difficulties in managing standards] In Umweltbundesamt (Ed.), Transparenz und Akzeptanz von Grenzwerten am Beispiel des Trinkwassers. Berichtsband zur Tagung vom 10. und 11. Oktober 1995 (mit Ergänzungen), [Transparency in and acceptance of standards. The case of drinking water] (pp. 133–150). Berlin: Erich Schmidt Verlag.)

■ UNS-Working Paper 11

Oberle, B.M., Meyer, S.B., & Gessler, R.D. (1995). **Übungsfälle 1994: Ökologie als Bestandteil von Unternehmens- strategien am Beispiel der Swissair**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

■ UNS-Working Paper 12 (Out of Print)

Mieg, H.A. (1996). **Managing the Interfaces between Science, Industry, and Society**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

(Published as: Mieg, H.A. (1996). Managing the interfaces between science, industry, and society. In: UNESCO (Ed.), World Congress of Engineering Educators and Industry Leaders (Vol. I, pp. 529-533). Paris: UNESCO.)

■ UNS-Working Paper 13 (Out of Print)

Scholz, R.W. (1996). **Effektivität, Effizienz und Verhältnismässigkeit als Kriterien der Altlastenbearbeitung**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

(Published as: Scholz, R.W. (1996). Effektivität, Effizienz und Verhältnismässigkeit als Kriterien der Altlastenbearbeitung. [Efficacy, efficiency and appropriateness as criteria for evaluating soil remediation cases] In: Baudirektion des Kantons Zürich in Zusammenarbeit mit ETH-UNS (Eds.). Grundsätze, Modelle und Praxis der Altlastenbearbeitung im Kanton Zürich: Referate zur Altlastentagung 1996 [Principles, models and the administrative practice of soil remediation in the Canton of Zurich] (pp. 1–22) Zürich: AGW Hauptabteilung Abfallwirtschaft und Betriebe.)

■ UNS-Working Paper 14 (Out of Print)

Tietje, O., Scholz, R.W., Heitzer, A., & Weber, O. (1996). **Mathematical evaluation criteria**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

(Published as: Tietje, O., Scholz, R.W., Heitzer, A., and Weber, O. (1998). Mathematical evaluation criteria. In H.-P. Blume, H. Eger, E. Fleischhauer, A. Hebel, C. Reij, & G. Steiner (Eds.), Towards sustainable land use (pp. 53–61). Reiskirchen: Catena.)

■ UNS-Working Paper 15

Steiner, R. (1997). **Evaluationsbericht: Bewertung der obligatorischen Berufspraxis im Studiengang Umweltnaturwissenschaften durch Betriebe und Studierende**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

■ UNS-Working Paper 16 (Out of Print)

Jungbluth, N. (1997). **Life-cycle-assessment for stoves and ovens**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

(Published as: Jungbluth, N. (1997). Life-Cycle-Assessment for stoves and ovens. 5th SETAC-Europe LCAS Case Studies Symposium, (pp. 121–130), Brussels.)

■ UNS-Working Paper 17

Tietje, O., Scholz, R.W., Schaerli, M.A., Heitzer, A., & Hesske, S. (1997). **Mathematische Bewertung von Risiken durch Schwermetalle im Boden: Zusammenfassung des gleichnamigen Posters auf der Tagung der Deutschen Bodenkundlichen Gesellschaft in Konstanz**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

■ UNS-Working Paper 18

Jungbluth, N. (1998). **Ökologische Beurteilung des Bedürfnisfeldes Ernährung: Arbeitsgruppen, Methoden, Stand der Forschung, Folgerungen**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

■ UNS-Working Paper 19 (Out of Print)

Weber, O., Scholz, R.W., Bühlmann, R., & Grasmück, D. (1999). **Risk Perception of Heavy Metal Soil Contamination and Attitudes to Decontamination Strategies**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

(Published as: Weber, O., Scholz, R.W., Bühlmann, R., & Grasmück, D. (2001). Risk Perception of Heavy Metal Soil Contamination and Attitudes to Decontamination Strategies. *Risk Analysis*, Vol. 21, Issue 5, pp. 967–967.)

■ UNS-Working Paper 20 (Out of Print)

Mieg, H.A. (1999). **Expert Roles and Collective Reasoning in ETH-UNS Case Studies**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

(Published as: Mieg, H.A. (2000). University-based projects for local sustainable development – Expert Roles and Collective Reasoning in ETH-UNS Case Studies. *International Journal of Sustainability in Higher Education*, Vol. 1, No. 1, pp. 67–82.)

■ UNS-Working Paper 21

Scholz, R.W. (1999). **«Mutual Learning» und Probabilistischer Funktionalismus – Was Hochschule und Gesellschaft von einander und von Egon Brunswik lernen können**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

■ UNS-Working Paper 22 (Out of Print)

Semadeni M. (1999). **Moving from Risk to Action: A conceptual risk handling model**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

(Published as: Semadeni, M. (2000). Moving from risk to action: A conceptual risk handling model. In R. Häberli, R. Scholz, A. Bill, & M. Welti (Eds.), Proceedings of the International Transdisciplinarity 2000 Conference: Transdisiplinarity – Joint Problem-Solving among Science, Technology and Society. ETH Zurich. Workbook I: Dialogue Sessions and Idea Market (pp. 239-234). Zürich: Haffmanns Sachbuch Verlag.)

■ UNS-Working Paper 23 (Out of Print)

Güldenzoph, W. & Scholz, R.W. (2000). **Umgang mit Altlasten während dem Transformationsprozess im Areal Zentrum Zürich Nord (ZZN)**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften

(Published as: Güldenzoph, W., Baracchi, C., Fagetti, R., & Scholz, R.W. (2000). Chancen und Dilemmata des Industriebrachenrecyclings: Fallbetrachtung Zentrum Zürich Nord [Opportunities and dilemmas in the recycling of industrial "brownfields": Case study city center Zurich North]. DISP 143 [Documents and Information on Local, Regional, and Country Planning in Switzerland], 36, 10-17.)

■ UNS-Working Paper 24

Semadeni M. (2000). **Soil and Sustainable Land-Use**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften

■ UNS-Working Paper 25

Sell J., Weber, O., & Scholz, R.W. (2001). **Liegenschaftsschatzungen und Bodenbelastungen**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften

■ UNS-Working Paper 26 (Out of Print)

Hansmann, R., Hesske, S., Tietje, O., & Scholz, R.W. (2001). **Internet-unterstützte Umweltbildung: Eine experimentelle Studie zur Anwendung des Online-Simulationsspiels SimUlme im Schulunterricht**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

(Published as: Hansmann, R., Hesske, S., Tietje, O., & Scholz, R.W. (2002). Internet-unterstützte Umweltbildung: Eine experimentelle Studie zur Anwendung des Online-Simulationsspiels SimUlme im Schulunterricht. Schweizerische Zeitschrift für Bildungswissenschaften, Nr. 1/2002.)

■ UNS-Working Paper 27

Scholz, R.W. & Weber, O. (2001). **Judgments on Health Hazards to Soil Contamination by Exposed and Not-exposed Residents**. Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

■ UNS-Working Paper 28

Scholz, R.W., Steiner, R., & Hansmann, R. (2001). **Practical Training as Part of Higher Environmental Education.** Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

■ UNS-Working Paper 29

Hansmann, R., Scholz, R.W., Crott, H.W., & Mieg, H.A. (2001). **Education in Environmental Planning: Effects of Group Discussions, Expert Information, and Case Study Participation on Judgment Accuracy.** Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

■ UNS-Working Paper 30

Laws, D., Scholz, R.W., Shiroyama, H., Susskind, L., Suzuki, T., & Weber, O. (2002). **Expert Views on Sustainability and Technology Implementation.** Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

■ UNS-Working Paper 31

Flüeler, T. (2002). **Robust Radioactive Waste Management: Decision Making in Complex Socio-technical Systems. Part1 = Options in Radioactive Waste Management Revisited: A Proposed Framework for Robust Decision Making; Part 2 = Robustness in Radioactive Waste Management. A Contribution to Decision Making in Complex Socio-technical Systems.** Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

(Part 1 published as: Flüeler, T. (2001a): Options in Radioactive Waste Management Revisited: A Framework for Robust Decision Making. Journal of Risk Analysis. Vol. 21. No. 4. Aug. 2001:787-799.

Part 2 published as: Flüeler, T. (2001b): Robustness in Radioactive Waste Management. A Contribution to Decision-Making in Complex Socio-technical Systems. In: E. Zio, M. Demichela & N. Piccinini (eds.): Safety & Reliability. Towards a Safer World. Proceedings of the European Conference on Safety and Reliability. ESREL 2001. Torino (I), 16-20 Sep. Vol. 1. Politecnico di Torino, Torino, Italy:317-325.)

■ UNS-Working Paper 32

Hansmann, R., Mieg, H.A., Crott, H.W., & Scholz, R.W. (2002). **Models in Environmental Planning: Selection of Impact Variables and Estimation of Impacts.** Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

■ UNS-Working Paper 33

Schnabel, U., Tietje, O., & Scholz, R.W. (2002). **Using the Power of Information of Sparse Data for Soil Improvement Management.** Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

■ UNS-Working Paper 34

Weber, O., Reiland, R., & Weber, B. (2002). **Sustainability Benchmarking of European Banks and Financial Service Organizations .** Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

■ UNS-Working Paper 35

Kammerer, D., Sell, J., & Weber, O. (2002). **Evaluation of AIJ Project Proposals – Potential Contribution to Sustainable Development.** Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

■ UNS-Working Paper 36

Scholz, R.W., Mieg, H.A., & Weber, O. (2003). **Wirtschaftliche und organisationale Entscheidungen.** Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

(Published as: Scholz, R.W., Mieg, H.A., & Weber O. (2003). Wirtschaftliche und organisationale Entscheidungen, In: Auhagen & Bierhoff. Wirtschafts- und Organisationspsychologie.)

■ UNS-Working Paper 37

Scholz, R.W. & Binder, C. (2003). **The Paradigm of Human-Environment Systems.** Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

■ UNS-Working Paper 38

Hansmann, R., Crott, H.W., Mieg, H.A., & Scholz, R.W. (2003). **Is Group Performance Improved by Evaluating Task Difficulty and by Knowing about the Differential Effects of Conformity?.** Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.

■ UNS-Working Paper 39

Binder, C., Hofer, C., Wiek, A., & Scholz, R.W. (2003). **Transition process towards regional wood flows by integrating material flux analysis and agent analysis: The case of Appenzell Ausserrhoden, Switzerland.** Zürich: ETH Zürich, Umweltnatur- und Umweltsozialwissenschaften.