Project [56] SUSFISH Burkina Faso

Sustainable Management of Water and Fish Resources in Burkina Faso (SUSFISH)

A SYNTHETIC OVERVIEW OF THE SUSFISH PROJECT Society Meets Ecology

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Reporting period: November 2011 - November 2014
Final Report submitted: January, 2015

Financed by
Austrian Development Cooperation

Implementing Organizations

Current questions in sustainable water management and higher education

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To be cited as: SUSFISH Consortium (2015) Sustainable Management of Water and Fish Resources in Burkina Faso - a synthetic overview of the SUSFISH project. Supported by the Austrian Partnership Programme in Higher Education & Research for Development, http://susfish.boku.ac.at/download.htm.

Funded by APPEAR (Austrian Partnership Programme in Higher Education and Research for Development) Project 56. Financed by the Austrian Development Cooperation

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Introduction

The SUSFISH project was designed to strengthen in-country capacities for science, policy and practice to establish the basis for better water quality and sustainable fisheries in Burkina Faso. This means building scientific capacity to monitor and assess the dynamics of reservoir ecological services (fish, water), the educational capacity to train scientists and technicians in these concepts and methods, and the institutional capacities in management and policy formulation that are linked with research and education in the sphere of water and fisheries in Burkina Faso. Combining these research, education and policy goals boosts the potential for sustainable development in Burkina Faso (see Figure 1).

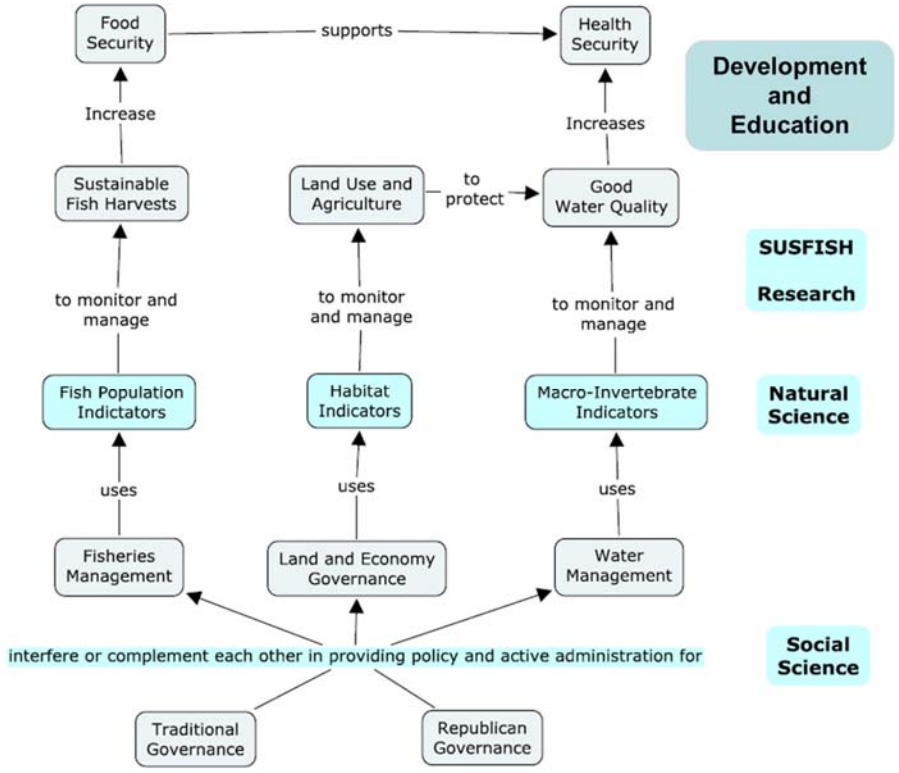


Figure 1 – SUSFISH research products related to food security, sustainable fisheries, water quality boost the potential for development and education in Burkina Faso.

The project was launched in November 2011 and is being undertaken by a consortium of in total 7 institutions of higher education and development in Burkina Faso and Austria, namely:

- Institute for Environment and Agricultural Research, Ministry of Research and Innovation, Ouagadougou, Burkina Faso
- General Directorate for Fish Resources, Ministry of Animal and Fish Resources Ouagadougou, Burkina Faso

- International Union for Conservation of Nature and its Resources (IUCN), West and Central Africa, Programme Burkina Faso
- Polytechnic University of Bobo-Dioulasso, Burkina Faso
- University of Ouagadougou, Burkina Faso
- University of Vienna, Austria
- International Institute for Applied Systems Analysis (IIASA), Laxenburg Austria
- BOKU University of Natural Resources and Life Science, Vienna, Austria

The work was also done in close cooperation with Dr. Piotr Magnuszewski, Centre for Systems Solutions Wroclaw, Poland and Prof. Phillipe Cecchi from the program 'IRD G-eau' and APPEAR project "MEAMP Elements for a Burkina Faso national pharmacopoeia: monographs redaction and quality control of endangered antimalarial medicinal plants" and finally but not least the Institut Français de Burkina Faso and Vienne.

We want to thank all donors, partners and people who supported and are still supporting our work – especially Mrs. Gritschi Kerl for sharing all her knowledge and great experience with us. We are grateful that the BOKU Center for International Relations (ZIB) funded the Austrian students stay in Burkina Faso with a scholarship for short-term scientific work abroad (KUWI), awarded directly by the University of Natural Resources and Life Sciences. Furthermore, we want to thank the Austrian Development Agency and Appear Programme (Austrian Partnership Programme in Higher Education & Research for Development) for financing the SUSFISH Project (Sustainable Management of Water and Fish Resources in Burkina Faso), in the frame of which this thesis was written.

Dr. Zettel and especially Dr. Jäch from the Natural History Museum Vienna were very helpful and patient with the identification of Hemiptera and Coleoptera, respectively. The same support was given for fish identification by Prof. Jos Snoeks and his team from the Africa Museum in Tervuren, Belgium. Special thanks to the "Freunde des Haus des Meeres" in Vienna. Our SUSFISH student Paul Meulenbroek´s master thesis on „fish habitat use in the volta catchment" was awarded with the Ferry-Starmühlner-Preis for the best thesis on freshwater fish research in 2013. Prof. Ott from the University of Vienna highlighted the enourmous effort and competence of both Austrian and African students. At the final SUSFISH meeting this award benefit will be shared with the Burkinabe collegues.

In June 2013 a multi-day workshop was organized in Vienna to show the potential for sustainable solutions that can emerge when a diversity of perspectives from social and natural sciences, from academia, government and informed lay community are integrated in the pursuit of policy reform.

During this workshop more than 100 visitors from 12 countries attended more than 30 scientific presentations and discussions, also prepared for the public. One highlight was the Austrian film premiere "Les grands Barrages en Afrique de l´Ouest" a documentary film produced by IUCN and ECOWAS (Economic Community of West African States). Speakers came from 12 different scientific and public institutions, working in theory and practice on

concepts of life sciences, development research, biology, ecology, food security, sociology, anthropology, medicine, education, gender, system analyses and political topics. Beyond that, intensive and fruitful discussions about partnership, higher education, participation, gender but also climate change, human impacts ecosystem services helped us to understand each other better.

Over three years the project successfully generated a diverse array of information useful for sustainable fisheries in the areas of aquatic ecology, policies and legislation, socio-economies, anthropology and gender in fisheries and water resources management. The project's demand-driven agenda requires at its end that project partners go back to the beneficiaries (e.g stakeholders, scientists, fisherman, students) and share results, information and knowledge co-created with all of them.

This was the main objective of the "SUSFISH Final Symposium" that took place at the Centre National des Archives in Ouagadougou 15-16 July 2014. The second aim of the symposium was to support future cooperation between partner institutions. Its specific objectives were (1) to oresent the project results among researchers (research and education), (2) share relevant information with decision makers at other stakeholders and (3) to discuss future steps.

About 100 persons attended the symposium: researchers, students and representatives of institutions (government, NGO and education) that are expected to use and implement the SUSFISH results. Some twenty-four presentations were given (see the programme in the appendix). The main focus was oriented towards the most prominent research results, the lessons learned and the prospective areas for further research and activities in sustainable fisheries and their socioeconomic effects.

Several recent developments and news remind us how complex and essential integrated approaches are. Based on the experiences of the past years and new findings, we want to reflect on whether sustainable solutions are possible on regional, national and international level. Today's development challenges demand integrated approaches that allow leveraging on synergies to obtain multiple benefits concurrently.

In SUSFISH it is also the aim to integrate gender issues at all stages of research. This approach requires new networks, new forms of cooperation to accord equal status to both genders, and target women explicitly as important actors. During reporting period the project team decided to focus on this challenge and to use gender sensitivity in order to contribute to a better understanding of social practice, complex interrelations of power relations and strategies of in- and exclusion in the fisheries and water sectors.

Main findings from SUSFISH activities and research

- More than 75 fish species and 61 families of macro-invertebrates have been identified and their spatial distribution described. Auchenoglanis gen. and Hydrocynus gen could be used as sentinel genera. Clarias sp and Sarothorodon sp increase with pressures, unlike other species, e.g. Alestes sp and Schilbe sp., which are sensitive and decrease in number as pressures rise.

- There are important differences between the communities of benthic invertebrates in rivers and in reservoirs. Water plant habitats exhibit a higher taxa richness and diversity than sediment habitats.
- Biological assessment of water bodies in Burkina Faso is feasible.
  Two possible ways are considered 1) adapting an existing method or 2) developing an own methodology
- Definition of reference sites in typologically similar rivers and areas; larger data set comprising good, moderate and bad sites in different areas is necessary for future investigations
- Habitat and human pressures influence biodiversity
- Increase knowledge about Fish and Benthic Invertebrates – sampling method, taxonomy, distribution, ecology, and conservation status. Adaptation of determination keys for BF
- Development and implementation of a standardised monitoring system is necessary to protect waters and environment.
- Adequate biological assessment method enables policy makers and managers to enforce appropriate management plans will help to raise public awareness for the protection of water bodies
- An official (IUCN red) list of fish species and invertebrates, a national database of meta information on existing biophysical characteristics of fisheries, the diversity and conservation status of fish species and benthic invertebrates, the pressures on fish populations and methods of water assessment based on fish and macroinvertebrates are under development
- The population of direct fisheries stakeholders is estimated at about 32 700 persons (14% are women and 82 % men), 3 000 fishmongers (54% are woman). Between groups of stakeholders some disparities in the access to fish resources are noticeable: man vs. women, allochthon vs autochthons, youth vs. elderly. As a consequence preliminary results show unequal representation in decision-making committees and restricted access to information about laws, regulations and rights in the fisheries among those groups of society.
- The SUSFISH Project aims to integrate gender issues at all stages of research. This approach requires new networks, new forms of cooperation to accord equal status to both genders, and target women explicitly as important actors. During the reporting period the project team decided to focus on this challenge and to use gender sensitivity in order to contribute to a better understanding of social practice, complex interrelations of power relations and strategies of in- and exclusion in the fisheries and water sectors.
- The results of social science research show first, that macro-level policies and legislation are not known at regional and local levels. The national organization in charge of fisheries is unknown as well because no tangible activity is undertaken in the field or to target the direct stakeholders. The field police fisheries officers (foresters) are not inclined to work on fisheries in the areas of monitoring, surveillance and control. As a result, prohibited fishing methods are increasingly used. Second, both “republican” e.g. European democratic, and traditional institutions make relatively important contributions to the governance of water and fish resources. But the two systems have to be harmonized
- We observed that in Burkina Faso, fish intake contributes to improving food and nutrition security. Income from fish sales also helps improve the household food and nutrition security.

- As for capacity building and education strengthening, about 23 students (2 doctoral) and more than 20 masters) have been involved in SUSFISH. Several others are expected to be assisted.

The following sections of this report describe how different facets of SUSFISH built the foundations of these capacities for fisheries science, policy and practice. As previously noted, the core mission of the SUSFISH project was to deliver information that includes and cuts across disciplinary boundaries. As such, all the information reported below was done both for the biophysical sciences as well as the non-biophysical sciences, e.g. social, economic, political and anthropological sciences. Section 1.1 reports on the specific findings of fact that SUSFISH research established. Section 1.2 describes the key questions that remain outstanding with the completion of the SUSFISH project. Section 2 examines some of the important implications raised by SUSFISH research. Section 2.1 reports on what key experts and stakeholders in Burkina Faso consider are important trends and possible scenarios of concern growing out of current conditions. The relevant factors that ought to be investigated in order to explore what relationships might produce said scenarios are listed. Along with the questions raised in Section 1.2, these are meant to inform efforts to design future research agendas for Burkina Faso fisheries. Section 2.2 gives two examples of conceptual mapping exercises to illustrate how such systems analysis can elucidate what are some of the specific kinds of relationships, e.g. webs, chains, feedback loops, that could produce the scenarios in question.

Section 1. Key Knowledge Gains under SUSFISH

1.1 Lessons Learned

Even though reservoir fisheries and the science behind them are relatively young, the knowledge base associated with the activities and the social-ecological systems of inland fisheries is already prodigious and growing. The following section narrows the focus within this knowledge base to the facts that SUSFISH research generated in the biophysical and non-biophysical sciences. The emphasis on lessons learned highlights the fact that at this early stage many kinds of information, e.g. data, concepts, ideas, can contribute to establishing and maintaining sound science, policy and practice for inland fisheries in BF.

1.1.1. Biophysical Sciences

This section reports on findings of fact generated by field measurements and knowledge elicitation. These research activities were performed by SUSFISH partners, e.g. students, supervising professors, government agents, to address SUSFISH research questions related to the biophysical sciences, e.g. biology, chemistry, and ecology.

Table 1.1 – Critical Lessons Learned by Biophysical Science Research under SUSFISH

No.	Lesson Learned from Biophysical Science Research in Burkina Faso
1.1	Fish size, abundance and diversity are related to the quality of fisheries and habitat management
1.2	Fish presence and diversity are lowered by anthropogenic pressures
1.3	Benthic invertebrate presence and diversity are affected by anthropogenic pressures
1.4	Fish taxa can be used as bio-indicators of anthropogenic pressures in Burkina Faso catchments
1.5	Despite anthropogenic pressures fish presence and diversity remains higher if hydrological connectivity of the regional surface water network is maintained, allowing fish migration to replenish local population declines.
1.6	Benthic Macro-Invertebrate taxa can be used as bio-indicators of anthropogenic pressures in Burkina Faso catchments.
1.7	Benthic Macro-Invertebrate taxa can be used as bio-indicators of water body typology, and river morphology and structure in Burkina Faso catchments.
1.8	Using fish and invertebrate taxa to develop a bio-monitoring program in Burkina Faso is both feasible and necessary.

1.9	Water quality in BF can be monitored using abiotic (Conductivity, Water Quality) and Land Use-Land Cover (Habitat Type) parameters.
1.10	Fish productivity, abundance and diversity related to water temperature.
1.11	The most important anthropogenic threats to aquatic biodiversity in Burkina Faso are: Habitat loss or degradation > pollution of water bodies >> drought.
1.12	Fish biodiversity status: a significant fraction (56%) of fish species in Burkina is threatened

Lesson 1.1: Fishing activity was present in all study sites, but anthropogenic pressure on fisheries varies according to how much fisheries management occurs. Our results confirm that fish size and fish community diversity are associated with the degree and quality of management, both of fisheries directly and of the habitat surrounding the fishery. For example, the Nazinga site has relatively unimpacted habitat (land management) and has a closed fishing season that is well-regulated (fisheries management), and it has significantly larger fish and a higher share in adult fish than any other sampling site. Furthermore, both fish and BMI diversity are higher in protected areas than others, e.g. *Nazinga, Mare aux Hippo*. Just as important as the legal content of policy, just as important to biodiversity conservation is its execution at the appropriate level (subsidiarity) by well-organized and led local actors. For example, in Moussodougou the fisheries are directly controlled by a local association that effectively enforces rules. Situations with effective management are associated with an increased biomasses and abundance with large fish specimens

Lesson 1.2. Increasing intensity of anthropogenic pressure leads to declines in: 1. Diversity; 2. Some (potential indicator) species and also families; 3. Trophic level (the trophic level dropped from 3 to 2.5 at highly impacted sites.), and 4. Density and biomass of intolerant species. The number of fish genera found declines with number of pressures
Anthropogenic pressures on fisheries mostly occur in multiple form (clusters) and correlate amongst each other to create "cumulative effects." Agricultural pressures were present in 87% of our sites. 70% of all sites exhibited bad water quality (expert opinion). 50% had connectivity pressures (GIS), stream morphology is mostly still ok (SS)
In the Nakambe catchment only 13% of the area remained as natural vegetation, 76% is cultivated land and 11% is bare soil, water holding capacity has decreased 33% in 30 years.

Lesson 1.3. Benthic invertebrate sample data reflect water quality and surrounding land use. Some taxa respond positively to anthropogenic pressures. For example, the highest densities and abundance of snails were found in the investigation sites with intense agriculture and livestock's. Some BI taxa clearly responded negatively to anthropogenic pressures. The total number of taxa and the number of "sensitive" taxa, e.g. *Ephemeroptera (*Mayflies*)* and *Trichoptera* (Caddis Flies), declined as the amount of pressure increases.
The hierarchy of responses to anthropogenic pressures as indicated by benthic invertebrate data is as follows:
Ouagadougou Res. 2 < Koubri Ancien = Bagre-SW < Ziga < Nazinga-Naguio.

Lesson 1.4. Fish taxa can be used as bio-indicators of the impacts of anthropogenic pressures either in the positive or negative sense. For example, *Auchenoglanis* gen. and *Hydrocynus* gen. could be used as sentinel genera because it is not found in areas of high anthropogenic impact. *Clarias* sp. and *Sarothorodon* sp. increase with pressures, unlike other species, e.g. *Alestes* sp. and *Schilbe* sp., which are sensitive and decrease in number as pressures rise. *Hemichromis* and, especially, *Tilapia*, correlate positively with hydro-morphological pressure, but they respond negatively to chemical impacts.

Lesson 1.5. Study sites that are under anthropogenic pressure but have intact connectivity, e.g. fish can migrate to other parts of the water network, have a higher diversity than fragmented ones. This may be related to our observation that about 50% of all caught species are potamodromous, and therefore normally migrate for spawning. Connectivity is severely impacted by hydrograph modification and reservoir dams. More than ninety percent (90%) of the annual discharge in the Nakambe basin is held back by dams, causing massive hydrographical modification. Approximately eighty-nine percent (89%) of all sites in this study were regarded as under influence of hydrographical changes or residual flow.

Lesson 1.6. Various parameters of Benthic Invertebrate (BI) communities, e.g. Biodiversity can be used as Bio-Indicators of anthropogenic pressures in Burkina Faso catchments. BI data can therefore be useful to pre-classify human impacts. Our data indicates that land use affects water quality and results in a changed BI taxa composition. Therefore, a simple approach to distinguish different land uses can be used to envisage water quality. Especially the intensity of agricultural land use is a strong predictor of the biota's reaction.

Lesson 1.7. Various parameters of Benthic Invertebrate (BI) communities, e.g. Biodiversity can be used as Bio-Indicators of water body typology, and river morphology and structure in Burkina Faso catchments. Our research confirmed that water bodies of differently degraded morphology are colonized by different benthic assemblages and that structures like different water plants (macrophytes) show a two to three times higher taxa richness than samples collected in sediment habitats. BI communities also reflect their surrounding "water body type". This has been shown at the "local" scales. For example, benthic invertebrate assemblages of running waters can be clearly separated from the communities in ponds. Flow conditions (e. g. stagnant, lentic, lotic) have been verified as the prominent ecological predictor of the BI species composition. This also has been shown at the broader scales of "eco-regions," e.g. analyses of 17 reservoirs showed that different eco-regions/bioregions have distinctly different BI communities. We conclude that for water management purposes this means that the according concepts and measures must be separately developed for standing and running water bodies in different eco-regions. There are indications that among running waters a typological distinction must be made by separating intermittent and perennial streams (stream sections). These findings clearly show that in BF a reference conditions based assessment methodology to evaluate the ecological quality of water bodies can be developed. Thus BF would have a future assessment methodology that fulfills the highest level of the state of arts.

Lesson 1.8. Certain fish and invertebrate species can be used as bio-indicators to assess the ecological status (water quality) of aquatic habitats in Burkina Faso (see Lessons 1.1 to 1.7).

There is a clear need to develop a new monitoring system based solely on BF_data. Our research on historic data shows that screening and sampling methods currently in use elsewhere in Africa and the world do not generate reliable statistics when applied in BF water bodies. Technical development and application of a biological assessment of water bodies in Burkina Faso is feasible as a three tier system with increasing accuracy and precision can be established: level 1: a rapid field methodology; level 2: a Biotic Score; and level 3: a Multimetric Approach. A Biotic Score provides a valid and sound but – compared to the Multimetric approach - a less sophisticated biomonitoring tool for assessing the ecological quality of a water body. Although based on only a few sampling sites the Masters thesis of Koblinger & Trauner (2014) gave clear evidence that a Biotic Score can be developed in BF.

Lesson 1.9. Human influences and urbanization cause, among other parameters, increased conductivity levels and high oxygen demand. Our research in running waters shows a correlation between conductivity and ecological water quality: the lower the SASS-ASPT score, the higher the conductivity value. Water column conductivity varies between different meso-habitat sampling points, but still is an appropriate parameter for water quality because a) it correlates sufficiently well with anthropogenic impacts, and b) it is easy and cost-efficient to measure. Critical "tipping points" or thresholds for biodiversity were shown when diversity rapidly decreased when conductivity surpassed 120uScm^{-1} or when oxygen saturation surpassed 120%. All areas except for Nazinga (protected area) have O2 saturations above this value. The lower pressure sites have an O2 Median >80% <100% and the more impacted sites have a median O2 saturation value >50% <75%.

Lesson 1.10. With increasing ambient temperature of the water column, productivity of a water body increases as well, resulting in higher abundances and more diverse species richness (Figure 10, Ref.:8). Abundance and richness reach a maximum between 29-31°C and the sudden drop of abundance and species richness indicates the maximum tolerance of some of the local fish species. Reservoirs can reinforce this trend of the heating up of the water bodies.

Lesson 1.11. Broadly, in Burkina Faso the presence, diversity, trophic level, density and biomass of certain fish and benthic invertebrate genera and species respond negatively to a range of anthropogenic pressures. These impacts include over fishing, hydrological alteration, agriculture, water quality, migration barriers, morphological alteration and loss of habitat (Stranzl 2014).

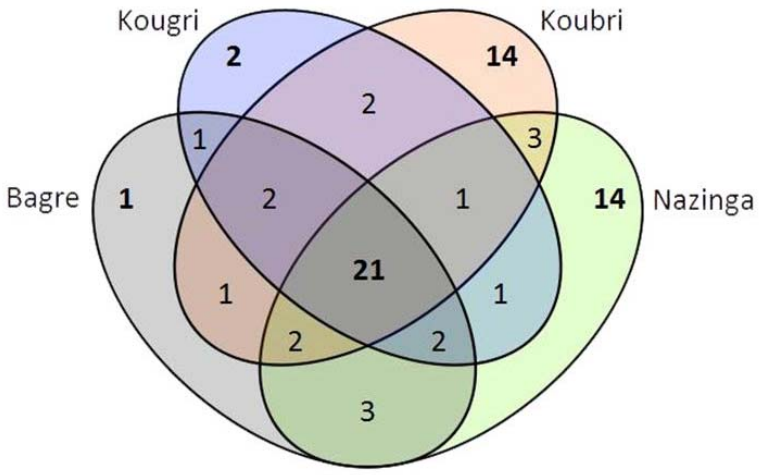
Table 1.2 – Anthropogenic threats to Aquatic Species in West African Catchments (Smith et al. IUCN Red List of West African Species)

	Percent of Aquatic Species Threatened	
Anthropogenic Threat	**Endangered Species**	**All Species**
Habitat Loss or Degradation	88	50
Agriculture	48	32
Mining	28	08
Wood Harvest	54	23
Human Settlement	20	06
Dam	11	04
Invasive Alien Species	04	08

Harvesting	05	07
Pollution of Water Bodies	55	20
Agriculture	24	12
Domestic	12	03
Commercial / Industrial	31	08
Oil Slicks	07	02
Sediment	25	08
Drought	07	17
Human Disturbance	04	02
Unknown	01	27

Lesson 1.12. At the national level, a preliminary red listing of the fish species shows that 24.6% of the 152 evaluated species are Critically Endangered, 8.4% Endangered and 22.5 are Vulnerable.

Comparing the biodiversity of 4 main sampling sites (Nazinga, Bagre, Koubri and Kougri)



Number of exclusive fish species for each of the main sampling sites, shows the local diversity

1.1.2. Social Sciences

This section reports on findings of fact generated by field measurements and knowledge elicitation. These research activities were performed by SUSFISH partners, e.g. students, supervising professors, government agents, to address SUSFISH research questions related to the non-biophysical sciences, e.g. sociology, economics, policy and anthropology.

Table 2 – Critical Lessons Learned by Social Science Research under SUSFISH

No.	Lesson Learned from Social, Economic and Political Science Research in Burkina Faso

2.1	Because of multiple kinds of legal and administrative statuses for fisheries according to reservoir type (large or small scale), there are gaps between National and lower levels of governance.
2.2	A link between law and practices to monitor fisheries is missing (law is not adopted to practice). Therefore little effective police monitoring or enforcement of fishing practices at the lower levels, e.g. smaller-scale fisheries.
2.3	Effective management of fisheries is blocked by failure to harmonize Republican and Traditional institutions.
2.4	Lack of historical data and statistics hampers efforts to measure progress and manage policy and fisheries practices accordingly.
2.5	Fisheries resources are not equally accessible to all actors.
2.6	Creation and enforcement of fisheries policy is hampered by the frequency of shifts of governance responsibilities (institutional nomadism) for fisheries management at the national Level (Administrative Flux).
2.7	Illegal equipment and practices are increasingly used in fisheries.
2.8	The long-term sustainability of fisheries is hampered by failure to maintain fisheries post-harvest infrastructure.
2.9	Progress in improving fishing methods is blocked by lack of capacity to learn or to organize.
2.10	Current institutional mechanisms are insufficient to implement and improve fisheries policies.
2.11	Fish play an increasing role in the economy and diet of Burkina Faso, but local production stagnates, and fish consumption is only 30% of WHO recommendations.
2.12	The role of fish in protecting health includes an increasing contribution to protein and energy intake (depending on fish quality and hygienic conditions in terms of fish processing (conservation).
2.13	Traditional institutions still play a role, but republican law is preeminent in fisheries policy and management.
2.14	Traditional institutions play vital role of reaffirming identity of communities reliant on aquatic ecosystems and thereby broadly influence water and fish management.

2.15	The importance of the division of labour, financing, responsibilities between male and female actors in fisheries is not fully considered by those who make and/or enforce policy in Burkina Faso.
2.16	The integration of a gender sensitive approach in fisheries policy and management needs an inter-ministerial cross sector cooperation.
2.17.	Discriminating practices towards women are anchored in structural disparities.
2.18.	Gender disparities in socio-ecological research results influence (manipulate) strategic planning at policy making level for sustainable fisheries management in Burkina Faso.

Lesson 2.1. At the lower governance levels below the national level, e.g. regional and local, the structural differences of fisheries management in BF take effect. For instance institutions, such as macro-level policies and legislation or the national organization in charge of fisheries, are not known because no tangible activity is visibly undertaken in the field or the activities do not target the direct stakeholders. According to our findings in case of the four largest reservoirs (*Ziga, Bagre, Kompienga, Sourou*) there is good communication between the national and lower levels and management at that level is good. But communication is not so good for management organs devoted to smaller reservoirs, except for four fishing concessions given to the associations of the local fishermen (*Bapla, Moussodougou, Tandjari, Lera*) where the communication and management is good. By law there are two kinds of status of fisheries based on management type: *concession* and *PHIE* (*Perimetre Halieutique d'Intérêt Economique)*, i.e. a fishery that impacts the national economy. But actually, there are three categories of fisheries management: very large reservoirs that never dry out and fishing continues for much of the year (PHIE), and *concessions*, and "others" that have no legal status. Note: subsistence fisheries exist in all three categories mentioned above. Besides this, by law there are four categories of fisheries defined according to the use of the catch: commercial, subsistence, sport, and scientific. According to SUSFISH findings this categorization does not reflect the status quo. Besides subsistence fisheries all other categories are not represented significantly.

Into what category a fishery falls is a question of priorities of national policies - the PHIE are "nationally-important" reservoirs, whereas the latter are more "subsistence-level" fishing for local markets. For the former, management is organized at a professional level: most of the fishermen involved are professionals and are aware of the legislation or rules. However, there is a link between education and fisheries management. As illiteracy is common among fishermen and fish processors, at a lower, more local, level awareness of regulations as well as access to information on improving fishing methods can be blocked. At the local levels (subsistence fisheries) when officials ignore rather than engage (no monitoring or enforcement) local problems, the lack of engagement gives local fishermen no opportunity

to learn about fisheries policies through responding to them. Thus they remain largely uninformed about legislation and administrative policy. They do know some of the rules, but they rarely if ever observe them. Lower level agents perceive no functional links (e.g. communication) that tie GDFA staff with any of the decentralized lower level government layers. Therefore, most local fishermen are unaware of the GDFA or what its functions are. National legislation and policies are not known by any of the decentralized lower level government layers. In closing we must caution that this data was gathered during a transitional period (shifting responsibilities between people in different organizations) such that anyone interviewed would not claim responsibility.

Lesson 2.2. Theoretically, there are management plans, that include monitoring and implementation, for the 4 major reservoirs and for the 4 concessions, but for the other 1000 reservoirs there are mostly no plans, no monitoring or enforcement. As previously stated, in some of these smaller fisheries that monitoring is left to by forestry agents, NGOs or fishermen's associations. The field police fisheries officers (foresters) are not inclined to work on fisheries in the areas of monitoring, surveillance and control. As a result, prohibited fishing methods are increasingly used.

Staff from the General Directorate for Fisheries and Aquaculture (GDFA)
"Fisheries managers" are rarely if ever seen in the field monitoring fishing.
This relative absence can be explained by the two separate structures of fisheries management in Burkina Faso: hierarchical and functional.(as explained in Lesson 2.1).

As a matter of resources Staff of the decentralized lower level government layers do not invest any time, money, or equipment in fisheries management. Professional staff of national agencies, in this case foresters, are not inclined to expand their duties from forest management to surveillance and enforcement of fisheries. This reflects the uncertainty emerging from responsibility overlap as well as from institutional nomadism. The law was not adjusted to the actual situation. Until now the foresters should control the fisheries, but foresters are in the meantime in the Ministry of Environment and the management of fisheries is in the Ministry of Animal Resources. Inter-agency conflicts (agricultural staff vs. foresters) make it difficult to define the boundaries of agency responsibility, so without a clear mandate field officers are not inclined to monitor fisheries.

Lesson 2.3. Both "republican", e.g. European democratic, and traditional institutions make relatively important contributions to the governance of water and fish resources. But the two systems have to be harmonized. Despite such changes, e.g. The on-going development and refinement of Republican institutions can be one reason why a resurgence of traditional practices (sacrifice by fishermen, traditional fishing) is recently noted by the various actors. It is the combination of various elements of governance according to Balandier a "syncretism" of traditional and modern systems;". Traditional stress [conflict]

management seems to change or slip away leaving some room for modern management. Experiences of participatory management of natural resources show an appropriate way to resolve conflicts in the tension between the legitimacy of traditional and modern perspectives. However, the patent failure of governance institutions to function at all levels and succeed in managing sustainable fisheries undermines trust, and this trend is exacerbated by emergent problems like "elite capture" of participatory processes or the afore-mentioned failure to harmonize traditional and republican institutions.

Lesson 2.4. Lack of data (either absence or poor data quality) deprives any agency, government or NGO, of baseline information about any aquatic ecosystem's history. Measuring progress or decline in fisheries requires such baseline information. This applies not only to data on fishery production (harvest and post-harvest) but also to the number of fishing persons, etc.

Lesson 2.5. Between groups of stakeholders some disparities in the access to fish resources are noticeable in general: man vs. women; allochthon (e.g. local indigenous) vs autochthons (foreigners from other nations or other regions); youth vs. elderly; educated [French, modern] vs. not educated; inside vs. outside networks or lobbies; different ethnic groups. But our in-depth studies showed that in the case of gender, we note that 14% of fishing persons are women, so exclusion is not total. As a consequence preliminary results show inequitable representation in decision-making committees and restricted access to information about laws, regulations and rights. This problem is further exacerbated by instances of "elite capture," where-in members of power elites take over decision-making processes to their financial and political benefit.

Lesson 2.6. Responsibility for developing and administering water and fishery policy shifted often between ministries and, hence, between departments and individuals.
Some fishermen claimed such shifts prevented surveillance that would have hindered them from using smaller net mesh sizes, a trend driving down fish size. The implications of such unpredictable shifts in responsibility are general feelings of frustration, helplessness and a lack of trust in governance, which are sustained when such nomadism perpetuates a state of ignorance by those officially responsible for management. If they pay any attention, such officials must be educated, so each problem is started and re-started so often that it appears trivial or is unsolvable and is easily ignored. This also works in reverse. When officials choose to ignore rather than engage local problems, the lack of engagement gives local fishermen no opportunity to learn about fisheries policies through responding to them. Thus they remain ignorant of legislation and administrative policy.

Lesson 2.7. Historical precedent and the lack of effective monitoring and enforcement are two important factors for the increase of illegal fishing methods. For instance the use of illegal fishing gear [to give only one example: mesh size] is common and has been the case for so long that it has becomes "normal" or "business-as-usual" that gives unofficial sanction to illegal fishing. The implications of such open and unchecked illegality are that the use of illegal equipment is no longer a conscious choice. One is no longer aware that one has "crossed the line" into illegality because "everyone does it."

Lesson 2.8. Infrastructure (fish ponds, refrigerators, fish-weighing scales, fish shops) are installed but either not maintained and allowed to decay or converted for private use. Such patent failures undermine trust in the government institutions that establish and execute programs, projects and policies to develop infrastructure.

Lesson 2.9. Of the many factors that hamper learning new fishing methods, one could be illiteracy, which is common among fishermen and fish processors. This blocks awareness of regulations as well as access to information on improving fishing methods. But it is also a question of adequate training modules for the target groups. For instance, some training courses have been developed, but they are not specialized for fishing. Rather they are framed for agriculture in general with a few sessions for fishing and aquaculture. Furthermore, this training is not generally available across all BF, and not comprehensive or detailed enough to really make a difference.
Learning new methods is further hampered by insufficient credible expert advice. In 13 regions there is no expert in fisheries and aquaculture available to advise local fishermen seeking to learn new practices. This mandates that fisheries consultancies should be established at the local, regional and national levels.
The spread of information about new methods is also hampered by lack of organization. Most of the fishermen and fish processors are not organized in professional groups in which access is limited to those in the profession. When they are, the functioning of such groups is questionable (elite capture). Indeed conflicts of leadership are often noticeable even when the association functions more or less well.
This lack of local organizing capacity hinders efforts for bottom-up leadership in fisheries management to fill the gap left by failure from the top, the national level. Very few if any local sustainability initiatives are started, often blocked by the perception that they lack resources, usually money.

Lesson 2.10. Failure in four areas hinders efforts to administer and improve fisheries policies.
1. Failure to integrate local knowledge: Policy formulation and implementation reflects local realities only partially. This is because input by local people to policy creation or administration is blocked by lack of capacity to constructively participate. The reasons for this lack of capacity are multiple: lack of funding to support participation, lack of experience or training in participation (people), lack of effective processes of participative democracy (governance). Such governance breakdowns as Elite Capture are especially damaging in this regard.
2. This lack of inclusiveness is reinforced by chronic failure to evaluate policies periodically and improve them. Such periodic policy review requires rigorous measurement of policy impacts and could identify where lack of local involvement harms policy creation or administration.
3. Even in the absence of local participation, national level policy makers have failed to make national vision of fisheries operative. A national "vision" has been recorded, but it remains theory on paper, not a practical, working vision that informs policy and implementation. The implications of such failures of leadership is that lack of a vision means that local as well as regional and national actors have no paradigm of fisheries

development to rally around and use as a baseline against which to measure policy performance.
4. Failure to cohere and harmonize policies of different ministries hinders efforts to improve policy. Fisheries sustainability depends on integration of policies governing a range of diverse activities, e.g. water, agriculture, forests, mining, tourism. Institutional nomadism contributes to this failure to create compatible policies or integrate them. This failure to harmonize policies across different governance levels is linked to or ineffective efforts to decentralize power to regions while maintaining a functioning governance structure that works across all levels.

Lesson 2.11. Fish economy: Fish consumption rose in BF when financial and economic crises, e.g. devaluation in 1994, drove livestock exportation up as much as 94%, increasing the meat price. This shift was also driven by improvements in livelihoods, especially increases in income in urban areas.
Fish Landings: While reliable data is lacking, expert opinion commonly asserts that captures fisheries production is declining, especially in high pressure areas. This could be related to the combination of many factors including climate change, human factors and lower natural productivity. This development is opposed by an increasing demand for fish according to international nutritional health recommendations. Average fish consumption was with 3.5 kg / capita / year in 2009 in Burkina Faso very low, compared to 15 kg in Côte d'Ivoire, 7kg in Mali and 12 kg in Senegal. This level of consumption is far from the WHO recommendations (12 kg / capita / year) and the global average was 18.6 kg / capita / year in 2010.
Furthermore only 20% of the domestic supply in 2011 came from domestic production, according to the *Direction Générale de la Pêche et de l'Aquaculture*. Following the National Strategy for fish and aquaculture development (official policy as of 2011), with this increasing demand on fish and the high percentage of fish imports to Burkina Faso in mind the current challenge for the sector of fisheries resources is increasing 40% per year domestic production through aquaculture.

Lesson 2.12. Fish and health: fish is an increasingly important part of the diet. This is especially so in rural areas where meat is less available and expensive. Fish is more affordable, is healthy (low fat) and can be applied in different ways, e.g. to name one example: complement breast-feeding.
Fish Contributions to Household Diet

- Percentage of Households with Fish Consumption: 1d/week (38%), 1 to 2 d/week (28%), daily (34%).
- Fish more affordable (less expensive and available in smaller portions) for most (88%) of household domestic heads (women)
- Average daily expense for fish purchase (150 Francs CFA)
- Fish contribution to total energy in diet (kcal): 31.5 to 45%
- Fish contribution to total protein in diet: 25 to 78.3%
- Fish contribution to total protein to complement breast-feeding in diet of infants: 82.2%

- the highest percentage of fish contribution to household diet was stated in families of fishermen or fish processing women

However, the contribution of fish to health improvement depends on fish quality. Findings on microbiological and parasitological quality of commercial fish show differences in bacterial density linked to processing methods, and hygienic conditions of selling contexts. High prevalence of parasites was found only on fresh and smoked fish, the latter is probably the most commonly available form of fish protein.

The health risk from fishing can be reduced if functional links can be made between fishery management and the local health system for prevention of injury and illness, e.g. prevention of water-related risks like diarrhea and malaria. Microbial contamination of fish en route to market leads to decreases in the quality of fish in the diet and raises the question of quality control for food security at different points on the value chain.

Lesson 2.13. The preeminence of republican law in fisheries policy and management: Modern laws that govern fishery management include: RAF (National law: *Reforme Agraire et Fonciere*): governs the management of natural resources and allocates fishing on public waters in the state; and Forest Code: regulates fisheries conservation, management and development of fisheries and aquaculture. Fishermen groups or associations at the local level relay these rules.
Examples of fishing rules imposed by Republican law as observed by 5 groups or associations of fishermen or anglers in Burkina Faso (*Wramba, Dougou Yiriwaton, Yiguèbougo, Amicale des pêcheurs de Banfora)*

- Prohibition on fishing fry (growth stage smaller than juveniles, e.g. larvae)
- Prohibition on fishing in spawning areas
- Ban hawk net
- Weigh catches
- No cultivation at the edge of the dam
- Reducing the number of nets in times of recession
- Prohibited to fish Friday
- Prohibition on mesh less than 35 mm Economical implications: commodification of fish

The social implications of changes imposed by Republican governance include:

- Disarticulation of traditional governance
- An organization of sectors (Groups, Associations)
- New roles of women in the transformation
- Peasants were transforming as fishermen
- Resistance of populations to new regulations
- Use of nets of mesh <35 mm
- Practice of fishing without a license

*Lesson 2.14. T*raditional institutions reinforce the sense of aquatic ecosystems as "sacred space" at the heart of the life of surrounding communities. "Water bodies occupy an important place in the history of the study area. They are loaded with symbolism and contain very often places of worship.". Water-related traditional ceremonies, such as sacrifices meditated by the *Tengsoba* and/or the *Kotigi*, have the following aims: happiness of all people; good rainfall; peace in the village; the productivity of the dam; the safety of users. Examples of interventions mediated by traditional institutions (ceremonies) by local

authorities in three villages (*Mossodougou, Tengrela, Tiefora*): sacrifices in cases of drowning, (3); participation in fishermens' sacrifices (2); prohibition of fishing on Friday (1); presidency of the CGP (1); authorization to increase the price of fish (1); appointment as Chairman of the fishermen (1); expulsion of foreigners (1).

Lesson 2.15. Data on the division of labour, financing, responsibilities between male and female actors in the fisheries sector brought deeper insight to the high contribution of women to the sustainability of fisheries in Burkina Faso.
But their important roles are not fully considered by policy makers, institutions, authorities, associations, and society.
- to a large degree women are managing the work of local fishermen at financial and organizational level as well as in the area of fishing materials, but they are barely organized within an association or supported by an institution
- at policy level fisheries are considered as male domain, therefore women are disproportionately represented in policy development of fisheries.
- women's commercial activities in fisheries are contributing to a high degree to the families' income. Current statistical surveys confine the focus to fishermen's income and do not give adequate attention to fish processing as an economic driver within the entire product chain.

Their proportionate representation at the level of policy development in the fisheries would be very important in the areas of access to financial resources, management of natural resources, improvement of commercialization of fish.

Lesson 2.16. The elaboration of a strategy for the integration of a gender sensitive approach in projects and policies for fisheries will support the participation of female actors in the sector. But as findings showed the consideration of women's needs and strategic interests is often linked to other policy sectors such as health, nutrition, water management and education. The coordination and integration of research findings and policy recommendations between the involved ministries is crucial for the development of a comprehensive development plan.

Lesson 2.17. Structural disparities between female and male actors in fisheries and water management (such as work routines, legal regulations, social responsibilities, gender specific labour division,…) in terms of access to information about illegal fishing practices, financial support, education initiatives lead to discrimination and exclusion of women at the decision making level.
It is left to informal group activities or NGO related work to ensure (promote) female workers' participation in local governance processes.

Lesson 2.18. Socio-ecological research on fisheries in Burkina Faso is referring to data relying on local decision makers and stakeholders (managers, head of associations,..) viewpoints, who are mainly male. Policy recommendations therefore tend to reflect only a partial evaluation of the situation. The elaboration and implementation of gender sensitive protocols and tools for data collection brought new insights for social practices in the area of fisheries in Burkina Faso

1.1.3. Gender – Lessons Learned

Table 1.3. Lessons Learned from SUSFISH Research concerning gender asymmetries in Burkina Faso

No.	Lesson Learned concerning Gender in Burkina Faso
3.1	How individuals perceive and interpret events are conditioned by their expectations, which often do not fit with a complete and realistic understanding of gender issues in Burkina Faso.
3.2	Participation of female students in research can be improved when their individual needs are more effectively addressed with better financing, more flexible schedules for field research, and more responsible teamwork. Increased female participation in field research, e.g. knowledge elicitation and data collection, improved the quantity and quality of data collected on female subjects, such as in the fish processing industry.
3.3	At the political level in Burkina Faso the concept of gender is adopted from development policy. It offers a way to look at how social norms and power structures impact the lives and opportunities available to different groups of men and women. It explicitly includes other groups as well, such as vulnerable groups of a society, poor people, young unemployed etc. But in research practice this approach risks to remain theoretical and development driven, because it is distant from peoples' livelihoods and leads often to misunderstandings.
3.4	The representation of female students at PhD level in social and ecological sciences is very low. Therefore in SUSFISH a participation of female PhD students was not possible. SUSFSH research revealed that weak sensitivity towards gender inequalities in the conception of pedagogical programmes for primary, secondary and university education is a significant factor for this imbalance at tertiary level.
3.5	The GDFR lacks a specific policy and strategy to address gender issues in fisheries management. During SUSFISH research it became obvious that gender issues in policy making often lack the cross-sectorial dimension. A second obstacle is the perception of gender issues as a "women & development" phenomenon, without taking into account the relations between men and women, their disparate roles, accesses and rights in society. Thirdly, it is a challenge to address women's needs when they are consequently excluded from decision-making processes. The gender strategy for the GDFA that was elaborated in SUSFISH incorporated SUSFISH results and offers a gender sensitive approach in fisheries and water management in Burkina Faso.

Lesson 3.1. Our research confirms the experience of scientific research organizations in the North and elsewhere in Africa that women can play an increasing role in research when gender

considerations are taken into account so as to meet their individual needs. Such measures as better directed financing and schedule flexibility will allow them to become responsible members of research teams.

Lesson 3.2. Concerning gender aspects in the management of natural resources of fish and water, numerous activities were facilitated in SUSFISH in 2014 in order to ensure the participation of women, men, and vulnerable groups. This was done in collaboration with the WP leaders - in particular WPs 4, 5 and 7. The main objective was to focus on the consideration of socioeconomic roles attributed towards women as fish processors and to men in the field of water management and of the fisheries. It was very important to involve women working in the fisheries sector for data collection. These efforts were primarily supported by the implication of female students in fieldwork, who had a much better access to information than male students. Especially the leaders of WP4 and WPs 5 and 7 encouraged female students in the participation of their research team. The results show an impressive participation of fish processing women and the consideration of their positions, needs and knowledge.

Lesson 3.3. At the political level in Burkina Faso the concept of gender is adopted from development policy. It is a way of looking at how social norms and power structures impact on the lives and opportunities available to different groups of men and women. It explicitly includes other groups as well, such as vulnerable groups of a society, poor people, young unemployed etc. But at the practical level, it is a challenge to share this approach with practitioners, because gender is widely understood as a repartition of roles, functions and responsibilities between men and women. Equality is often understood as equity by numbers. SUSFISH activities at the local level showed that workshops and group discussions are very useful to negotiate a common meaning and later to analyze aspects of power relations and structural inequalities that lead to the discrimination of women. Even in research practice this approach risks to remain theoretical and development driven, because it is distant to peoples' livelihoods and leads sometimes to misunderstandings. SUSFISH is a trans-disciplinary project, which aimed to foster cooperation between policymakers, practitioners and researchers. The diversity of gender concepts of in social, political and ecological sciences required that we first host debates to negotiate a common understanding among specialists in order to work with it. The SUSFISH team changed the project plan and organized a series of workshops in order to develop a project strategy to integrate aspects of exclusion into the set of tools for field research (access to resources such as time, money, information, equipment, fish quality, etc., but also access to education, control as well as participation in decision making processes). Besides these toolkits one result of the multidisciplinary workshops was that there is the need for a strategy to integrate gender aspects in fisheries management and research. The results and strategic inputs were disseminated in many channels such as the *Maquis des Sciences* dedicated to Gender in fisheries organized in close cooperation with the IRD and the French institute in Ouagadougou. The multidisciplinary character of SUSFISH offered the opportunity to empirical research in 2014 we developed a more precise conceptualization of gender as an integrative approach in socio-ecological sciences.

Lesson 3.4. The low participation of women at all career levels in ecological sciences was a challenge for SUSFISH project management. By analyzing structurally and socially-caused disparities within academia, SUSFISH experts stated that this phenomenon is perceived as a decision of female academics, which is not related to social and economic factors. SUSFISH research showed that female students are often older than male students and have to fulfill duties such as child care, income generating activities and to integrate them in their scientific career planning. Their decision not to continue in the Burkinabe education system until they achieve a doctoral thesis is often linked to social constraints and not because of low interest. This lesson is validated by the fact that even the University of Ouagadougou considered the phenomena that female students' careers are hard to

continue in Burkina Faso when once interrupted because of pregnancy of high priority in its strategy 2014-2025. And thus this phenomenon is also linked to a structural deficit of girls' promotion at primary and secondary level.

Lesson 3.5. One outcome oft the SUSFISH workshops on gender perspectives in the research agenda was the recommendation to develop a gender strategy in fisheries for the GDFR for the integration of a gender sensitive approach in projects and policies for fisheries and water management, which was completed successfully in 2014. SUSFISH findings were evaluated and integrated in the elaboration of the strategy. Exchanges with the Burkinabè Ministry of Women and Gender contributed to the elaboration process as well. Furthermore the consideration of halieutic resources within the gender strategy plan of the Ministry of Agriculture could be proposed. In future this strategy will allow development of a tool to integrate scientific expertise and adaptive management in the fisheries sector- The work of SUSFISH contributed significantly to its elaboration. SUSFISH promoted successful planning and implementation of gender-sensitive activities, programs and strategies in the field of the fisheries (Plea for the consideration of gender in the action plan of MRAH) and contributed to better documentation of gender-specific research findings. Besides on national level the results and reflections of 2014 contribute to a better understanding of constraints and challenges for the reduction of gender disparities in PNSR (e.g. impacts of regulations) and to the elaboration of solution-oriented measures.

1.1.4. Education

Table 1.4. Lessons Learned from SUSFISH Research concerning Education in Burkina Faso

No.	Lesson Learned concerning Education in Burkina Faso
4.1	The potential for good research is diminished when selection criteria are applied based on development priorities rather than academic priorities.
4.2	Much more time is needed to fully develop the potential of supervisor-student relations as part of teamwork maturing. This may require more funding at the outset to give sufficient attention to this challenge.
4.3	Delays in processing visas and in payment can seriously damage an education program. Only candidates who can afford waiting without payment for several months will be successful.
4.4	It is not enough to simply have a Memorandum of Understanding (MoU) between partner institutions in the North and the South. Sufficient effort needs to be made to translate and interpret exactly what commitments are required in terms of curriculum (teaching and learning) to successfully achieve the academic degrees that the project proposes.
4.5	More resources need to be invested to eliminate language barriers (e.g. French to English) that reduce the learning capacity of students from the South when they study in the North.
4.6	Transdisciplinary and transnational research cooperation needs to be informed by deeper reflection on biases introduced by scientific (epistemic) and cultural presumptions. Cross-disciplinary workshops initiate reflection, debate and discussion and thereby provide a model for research training modules. With ongoing internationalization, the institutional

	and overall conditions of partner institutions in the North and the South are diverging, and asymmetries in the access to and use of information and technology become even stronger.
4.7	Applying science often requires negotiating the meaning of conflicting scientific positions, e.g. the concepts, theories and protocols embedded in the development of each discipline. Therefore, debate and discussion are preconditions for applied research, and groups of junior researchers (BA, MA, Phd-candidates) should be institutionalized (in social and ecological disciplines) at faculty/department level.
4.8	To succeed as researchers who support national policy formulation and in an international market for science, graduate students from Burkina Faso need additional skills in scientific practice to define research questions and independently carry out research projects. Their training needs to give them access to the best, latest and most appropriate methods as well as research findings internationally. A prerequisite is knowledge about the creation process of peer-reviewed publications. Often Burkinabè graduate students stop at the level of in-country reports or presentations in BF conferences and do not continue their work in follow-up proposals, presenting and networking on the international stage.
4.9	Structural deficits at the institutions: working conditions for junior and senior researchers often do not allow participation in the creative processes, cooperation, exchange, discussion that produce top-level research. More financial and structural support should be applied at the university and secondary school levels. Specifically, applied science training should be given increasing priority before the university level to foster integration of theory and practice in secondary education and better prepare students with potential to do scientific research at the graduate level.
4.10	The interdisciplinary approach enhanced the applicability of research results in the development of training curricula for practitioners in the fisheries sector as, for instance, the cooperation between health, social, biochemical and nutritional scientists within SUSFISH showed.
4.11.	To work as a student or researcher in the field of development research needs training in understanding complexity. The personal involvement of the researcher is crucial to the whole process. Joint field work in teams should become a core element of curricula and should be also institutionalized at the partner institutions.

Lesson 4.1 - The promotion of junior researchers and scientists is a key instrument for capacity-building measures in research cooperation. The priorities of the Austrian Development Program for Cooperation in terms of the promotion of higher education systems in Burkina Faso are focused on strategic goals which are in some aspects hard to combine with the main goals of research cooperation. One reason could be that the criteria for good research cooperation do not fully overlap with those for development cooperation programs.. We experienced this gap regarding the selection of PhD candidates from the South for funding. The selection of candidates required a comprehensive (interdisciplinary and collaborative) search that produced a list of several candidates that was first prioritized by academics on the basis of scientific qualification criteria. This list was then judged by professionals in development based on gender and age criteria.

Lesson 4.2 – Structural deficits: Within the APPEAR program a student-supervisor relationship should be considered as a team and not more-or-less understood as a service delivery. Education is much more than a commodity that is shipped on a one-way street from North to South. It is an exchange of information mediated by separate cultural frameworks. Joint supervision: Students are supervised part-time at a foreign (distant) institution in order to get trained in international high level science. But to fully develop such an exchange requires sufficient time, which means not simply three meetings over 4 years as is currently budgeted. Joint supervision needs close cooperation between partners. Joint supervision of doctoral students needs face-to-face contact between the teachers (travel costs should be covered)-In SUSFISH we managed the financial gap only by flexible management of budgetary dedication. Supervision should start early, even before visas are granted, such that students are better prepared when they arrive at partner institutions in the North. In a similar light, networking time must be reckoned in the design of PhD-educational programs.

Lesson 4.3 - Even if all applications are confirmed, it still takes (too much) time until the student can come to his host university. There were examples of successful applications which could not be realized because the student's career plans changed significantly during the time of waiting for the visa to be granted. Scholarships had to be reselected for a second time. This has consequences for the whole funding period for research cooperation. The standard funding model used by all donor institutions allocates 3 years. This three-year interval is a minimum for doctoral program (including defense) without travelling, visum, flight, administration, applications etc. Experiences in SUSFISH show that at least two more years are necessary to complete the doctorate within the schedule (including publications & final defense).

Lesson 4.4 – Many higher education institutions have adequate quality-assurance processes for domestic delivery. Bilateral arrangements between universities allow mutual identification of measures of quality: The Memorandum of Understanding (MoU) between BOKU and the University of Ouagadougou was very important for acceptance of students from the South at BOKU. Standardized curricula theoretically guarantee accreditation of degrees. In practice, comprehension of the partner's system is not ensured by the internationally-acknowledged framework. A lot of additional information and translation work was requested for the studies programme at BOKU in order to approve the official recognition of certificates. Quality assurance programs can be time consuming in terms of communication and information flows, but they justify the time invested when student training raises their work quality and lowers the need for revision.

Lesson 4.5 - Language barriers: The skills expected in scientific English (1. comprehension, 2. writing) can be a significant problem for students coming from African Universities to European research institutions – esp. in natural sciences and especially for students from Francophone nations. Through internationalization of higher education systems mobility and transnational education experiences are promoted to foster competitiveness, innovativeness, mobility, language skills, international working skills. Structural adaptations (e.g. the promotion of English as the language of tuition) should not only focus on attracting students from all (other) regions. Such strategic orientation should provide effective cross-cultural educational preparation for all university students and improve equity among them.. As it happened in SUSFISH lectures at the Northern partner's institution offer a basic training in scientific English, which is far more challenging than the "conversational" English classes offered in the South. But this often reveals a gap between training in scientific writing offered by host universities and the specific needs of the group of foreign students from partner institutions. Overall, this highlights the need for training in scientific writing in English in the South. But considering the nature of scientific partnerships we need an approach which is sensitive to power asymmetries, e.g. a comprehensive analysis of research /education specific differences and research impeding factors (access to literature,

languages, scientific writing and reading expertise, access to international scientific networks) as well as discriminating factors (e.g. language).

Lesson 4.6 - Methodological approaches differ depending on how they are embedded in different epistemic traditions (ways of recognizing and using knowledge). These differences challenge efforts to share and exchange experiences & develop new innovative, research related approaches. It highlights the danger of unilateral knowledge transfer (North-to-South) simply facilitating uncritical reflection of presumptions. Transnational teamwork & exchange should be emphasized to encourage methodological reflection and understanding (e.g. cluster analysis) for students and reflection of concepts on intercultural cooperation. For applied research in socio-ecology: if knowledge and training is lacking, the imbalance in power relations gets reinforced through transcultural cooperation (e.g. stereotypes are reproduced vice versa). In SUSFISH team work at the level of joint field work involved fruitful discussions on methodological approaches that were possible because a common understanding of research contexts and its socio-cultural conditions (gender, politics, ecology,..) was needed. These training experiences should be integrated in curricula at partner universities in the South (e.g. UO and UBD) as well the North (e.g. BOKU). The curriculum should also integrate training in increasing the rigor of empirical research through better understanding of theory and methodology.

Lesson 4.7 - Understanding any scientific approach thoroughly is important for science research and especially such applications as modeling: therefore 1. to question, to contest to try and create an individual approach 2. to learn to argue own (controversial) positions should become part of the academic training. Curricula development should integrate practice in these applications.

Lesson 4.8 - To succeed as high quality researchers in an international market for science as a graduate student from Burkina Faso additional skills in scientific practice are required at two levels.

1. to show initiative in defining their own research questions and independently carrying out the research. It is not enough to pass successfully a course (e.g. statistics). A student researcher needs to comprehend or properly apply the best, latest and most appropriate methods that were supposedly learned in the course.
2. to engage in making research findings available internationally. A prerequisite is knowledge about the creation process of peer-reviewed publications. Often Burkinabè graduate students stop at the level of in-country reports or presentations in BF conferences and do not continue their work in follow-up proposals, presenting and networking on the international stage by going abroad to conferences and becoming sufficiently known to international consortia so they are invited for follow-up work.

SUSFISH observations highlight the need for further in-depth studies on the education system in Burkina Faso as a whole, even before graduate level courses, in order to analyze hindering factors for students' international career development.

Lesson 4.9 - The higher education systems in both partner countries underwent substantial changes, but the experiences at national level differ largely. In Austria several years of applying the Bologna system required several periods of adaptation. In Burkina Faso the first generation of university teachers is applying BA/MA system for the first time, but still there are many courses which are taught following the old system. Since the University of Ouagadougou underwent a curricula reform there are more opportunities to experience this personal (active) involvement in the production of scientific knowledge. Besides

4.10. - A lot of emphasis was put on the implementation of the interdisciplinary approach of SUSFISH. The team organized a set of workshops to bring together diverse research findings and to

define joint lessons learned. This strategic project focus enhanced significantly the applicability of research results in the development of training curricula for practitioners in the fisheries sector as for instance the cooperation between health, social, biochemical and nutritional scientists within SUSFISH showed. To improve the nutritional status of pregnant women, SUSFISH results on the nutritional quality of food were used to formulate a training manual (advices, list of products, use of fish and other sources of proteins). A pilot project to train six midwives for several weeks is currently being implemented. Their ability to advice pregnant women in nutrition is now being assessed in the area of Sindou (Banfora).

4.11. Experiential Education – participatory science

To work as a student or researcher in the field of development research needs training in understanding complexity. But how do we approach complex and changing systems? In natural sciences we examine dynamics, that we anticipated. In social sciences we analyze the different actors along their social interactions and representations. But in both approaches the personal involvement of the researcher is crucial to the whole process. The SUSFISH team of experts understands doing research as an interactive process, which is - besides the interactions in the field - crucially shaped by the researchers' personal factors such as biography, languages, social class, nationality and gender. Therefore at all levels of cooperation we encouraged exchange of ideas and debate in order to negotiate the meanings of different concepts, theories and methods. This aim became significantly reinforced by the students' preparedness to participate in foreign research contexts. The two PhD-students from Burkina Faso, who studied in Austria and the four Austrian MA students who studied in Burkina Faso formed a group of young scholars who wanted to reflect on different research contexts. Together they had the opportunity to experience practical constrains and learn how to integrate this transcultural experience into the research process. It resulted in a joint data corpus as basis for several new research questions on bioassessment and management of Burkinabè water bodies and fisheries. At the end of SUSFISH the first generation of publications and theses shows an impressive contribution of junior scientists based on the jointly collected data during fieldwork.

1.1.5. Partnership

Concerning partnership, the important lesson is that communication via meetings, workshops and symposia for instance are important to strengthen partnership and share resources. Also, student exchange should be promoted in such project because it leads to effective sharing of knowledge, resources and experience. Moreover, this also reinforces the capacity of local institutions. Another important lesson we learned: a project design should particularly consider joint research activities for junior (and senior) scientists with adequate financial resources and flexibility in terms of time and coordination for a joint and continuous supervision. It is obvious that these efforts should be embedded in a greater process of discussion and involvement of the whole project team. The project design should also integrate system analysis elements because this exercise gives a real overview and summary of the project achievements to partners themselves and clearly highlights their different perspectives.

1.2 Important Remaining Questions

The knowledge base established by SUSFISH research is considerable, but it is only a good start towards the critical mass of information needed to inform the creation and reform of policy and practice for BF fisheries. The power of a transdisciplinary approach is that it provides a comprehensive overview by integrating insights from diverse perspectives. But this power is only realized by frequent reappraisal and revision of research questions and methods as new knowledge is gained. Improvement of this knowledge base requires active research into the most pertinent questions that remain outstanding after this round of research is completed. The following two sections identify some of the most critical questions in the biophysical sciences (Section 1.2.1) and the non-biophysical sciences (Section 1.2.2) that can profitably inform future research agendas in Burkina Faso and other West African nations facing similar challenges with inland fisheries.

1.2.1. Biophysical Sciences

This section describes outstanding research questions that remain after completion of analysis of data by SUSFISH partners striving to address SUSFISH research questions related to the biophysical sciences, e.g. biology, chemistry, and ecology.

Table 3 – Key remaining questions in biophysical sciences after SUSFISH

No.	Question remaining after biophysical science research under SUSFISH
3.1	How can we improve capacity to identify and classify fish and benthic invertebrates in Burkina Faso?
3.2	By what means can we develop protocols to standardize sampling for fish and benthic invertebrates?
3.3	What artificial methods can boost fishery productivity; what are their advantages and disadvantages, and how can we improve and apply them in Burkina Faso?
3.4	How can we develop methods to bio-monitor for indices of water quality and fishery integrity that are applicable in Burkina Faso?
3.5	How can we develop methods to use benthic invertebrates as bio-monitors for indices of water quality that are applicable in Burkina Faso?
3.6	By what means can we assess the resilience of fish communities to prolonged exposure to anthropogenic pressures, e.g. chronic stress and episodic shocks?
3.7	How can we assess the impacts of river network connectivity on fish ecology?
3.8	What protocols must be applied to develop an ecological classification of reservoirs and rivers that is applicable in Burkina Faso?

3.9	Which options for fish management require further data and testing to help improve the sustainability of fisheries in Burkina Faso?
3.10	What are the impacts of habitat use and preferences on: spawning, larvae, juveniles and adults of different fish species in Burkina Faso?
3.11	How can we distinguish the impacts of pressures on fish taxa, both alone as individual pressures and in different combinations (syngergism)?
3.12	What relationships exist between dam size, the dynamics of rivers and various fish communities and/or fish species in Burkina Faso?
3.13	What are the effects of invasive plants on fish diversity and productivity?
3.14	How can we more precisely assess the human impacts on water quantity and quality in reservoirs to better inform policy and practice?
3.15	How do adult fish size and egg production influence fishery productivity?
3.16	How do agricultural impacts affect fish communities and fishery productivity?
3.17	What academic programs will professionalize the skills and knowledge needed to monitor water and fisheries at the higher levels that the SUSFISH project aims for?

Question 3.1. Improve Capacity to Identify and Classify Fish and Benthic Invertebrates in BF: Managing aquatic ecosystems and fisheries based on indicator species will be greatly facilitated by better tools to identify and classify benthic invertebrates and fish in Burkina Faso. This requires development of specific BI and fish classification keys for Burkina Faso. For BI this could be done gradually, with simple keys on family level for less experienced users, followed by more detailed ones.

Further fish community surveys in Burkina Faso are also mandated by the fact that fully one third of species with red list status have not yet been classified at the world level, much less at national level. A determination key for the Burkinabé fish species is important to improve the quality of the accessed data. We worked with an West-African key, which contains more than 10.000 species, which makes determination very tiring and sometimes hardly possible. .

Question 3.2. Protocols to standardize sampling for fish and benthic invertebrates
A guideline for a standardized sampling of fish and BI for BF should be developed in order to build indices based on comparable data. These protocols should cover how to use Cast-Nets and electric fishing for streams and small water bodies. In reservoirs and large, lentic river sections other sampling methods to investigate include: Gillnets and longlines.

Question 3.3. Artificial methods to boost fishery productivity:
Fish Stocking: What impact(s) does fish stocking in reservoirs have on fish diversity, productivity and abundance of existing fish communities?
What impacts result from stocking potentially invasive species?

Aquaculture: What are the ecological consequences/risks of aquaculture for Burkina Faso's reservoirs? Can GIS modelling to assess aquaculture potential in BF capable of supporting research into this aspect, specifically for the West African/Sahel zone?

Dams and reservoirs: What are the ecological consequences/risks of aquaculture for Burkina Faso's reservoirs? is the GIS modelling to assess aquaculture potential in BF considering this aspect, specifically for the West African/Sahel zone?
Fish ladders and fish migration: Some fish from Burkina do migrate, and dams constitute barriers to this migration. Sometime fish ladders are built, but their efficiency was never tested. Are these ladders useful, and which kind of ladders are the most efficient? Some evidence suggests that broken dam infrastructure permits migration. To what exent is this true, and can it be applied in fish ladder design?

Question 3.4. Fish Communities and Bio-monitoring
The effectiveness of any index-driven management policies will increase with better knowledge of fish and BI taxonomy, distribution, ecology, and conservation status. Developing an index based on indicator species for water quality and quantity management in BF requires comparing impacted and reference sites. What are the experiences from other countries, e.g. Austria, other nations in Africa, Asia or the Americas? What are the significant constraints? ref. Deliverable 3.1. "..developing a fish-based index for water quality and quantity management in BF

What could be the effects / the contribution of SUSFISH to ecological assessment methods concerning the relativization of research results (e.g. South and West Africa) brings light to new knowledge about fish"

To help to increase the responsibility of local people for their aquatic environments ("you can only protect what you know and value"), the development of a simple and easy-to-use water quality evaluation system is necessary. A useful tool for this purpose would be a rapid field assessment tool, such as what has been developed for the Hindukush-Himalaya-Region. (see www.assess-hkh.at.)

Before promoting any new scoring system it is necessary to test it broadly in different regions of Burkina Faso." How would such a broad testing process be designed, and what different actors should be involved such that local people as well as academics and government agents take ownership and apply it? What is needed for this process how much time and who will use it? Scientists? Politicians?

Question 3.5. Benthic Invertebrates and Bio-monitoring.
SUSFISH field research shows that in BF a biological river/water quality assessment system 1) can be developed and tested in a reasonable short time (three years), 2) will meet the

criteria of the highest state of arts, and 3) can be established as a three tier system with increasing accuracy and precision:

Level 1: a Rapid Field Methodology (screening); Such methods are crude and simple, e.g. quick dips with a net, to rapidly and cheaply obtain data about the presence and diversity of aquatic fauna.

Level 2: a Biotic Score (BS);
Currently, development of Level 2, a BS, is most advanced. Although based on only a few sampling sites the master thesis of Koblinger & Trauner (2014) gave clear evidence that a Biotic Score can be developed in BF. BS values clearly reflect different degrees of stress intensity (e.g. expressed as intensity of agricultural land use or some chemical parameters).

Two possible ways (that can be combined) can be used to develop a BS: 1) adapting an existing method or 2) developing an own methodology to evaluate and describe the ecological status of water bodies. SUSFISH research shows the basic ability of the South African Scoring System (SASS), which is based on benthic invertebrates (BI) as bioindicators that react in measurable ways to environmental stress. To adapt the SASS for Burkina Faso the following activities need to be undertaken: a) scores for BI have to be adapted; b) BI species that are not listed in the SASS need to be assigned a score (e. g. *Ampullariidae, Paludomidae, Iridinidae, Chaoboridae*); c) separate systems have to be developed for running water and for reservoirs and the aspect of perennial or intermittent discharge has to be regarded; d) to be able to apply the reference condition approach eco-geographic regions with similar conditions have to be defined; e) a sufficient number of test sites needs to be investigated to cover the variety of reference, good, moderate, poor and heavily impacted sites as well as the effects of different stressors and impacts. Also the oxygen concentrations in the water influence the invertebrates' reaction accordingly; polluted or eutrophied water bodies show heavy under- or over-saturations.
A special emphasis must be given to adapt the biotic score methodology to classify stagnant waters and reservoirs, as these scoring systems were not designed to assess stagnant or lentic water bodies.
List of possible stressors that should be investigated with respect to their impact on the biota and the ecological balance & functions:

- Recreation
- Tourism
- Sport
- Religion (including holy fish, holy crocodiles)
- Fishery
- Drinking water
- Irrigation
- Near shore or shallow water agriculture
- Cattle drinking/washing
- Direct toilet/washing use
- Sewage dumping

- Point pollution by sewers/pipes

Level 3: a Multimetric approach (MMI).Need more here
A preliminary version (valid for a distinct area) of a Multimetric Index could be developed based on the work of Idrissa Kabore (PhD thesis). Several tested metrics show a high correlation with environmental variables and provide a clear gradient of the metrics reaction under stress. The discrimination ability tested so far is promising.

Question 3.6. Resilience of fish communities
The resilience of fish communities is broadly indicated by the persistence of some species in "high pressure" sites. Is the species composition of such sites predictable enough to usefully classify these assemblages as "communities," and if so, what is the fish composition like in "lowest anchor point"/sites with a maximum pressure intensity, e.g. The wastewater channels in Ouagadougou? How does fish species composition change across a range of sites exhibiting a diversity of pressures of different degrees of intensity? Under what conditions and under what kinds of restoration efforts at high-pressure sites do fish communities rebound, and how can we measure different rebound parameters, e.g. maxima, minima, overall dynamics?

Question 3.7. Assessing the impacts of river network connectivity on fish ecology
Does "artificialization" of hydrographic networks, e.g. cascades of infrastructures along hydro-graphic networks and the absence of fish by-passes, disrupt the hydrographic connectivity during the flooding periods and prevent fish to migrate upstream and then (re)colonize lakes and reservoirs ? How can such questions be tested? When is the best time for an assessment, and how can the seasonal aspects be standardized? For example, when we were fishing (at the beginning of an early dry season), some habitats were already drying out, while others were still connected.

Question 3.8. Ecological classification of reservoirs and rivers - applicable in Burkina Faso.
Reservoirs represent a unique type of water body on a worldwide scale, but most assessment systems do not provide the option to assess stagnant water bodies, a common situation in Burkina Faso. A method for classification and typology of reservoirs and broad, lentic reaches of rivers needs to be developed that is sensitive to BF conditions, where stagnant water bodies are usually under strong agricultural pressures.

The differences in catchment size and Strahler order as well as the different ecoregions eventually require a river typology for further analysis. According to Mano in prep. The biota in the Comoe catchment varies a lot. In the Nakambe catchment, there is a downstream gradient of fish species composition all the way down to Ghana. Development of these classification methods may require data from neighboring countries (Frimpong in prep. Fish Diversity in West Africa).

Question 3.9. Fish Management Policy Options to Investigate
Closed season, specific mesh sizes of the fishing nets, minimum or maximum landing size and protection state of rare species could improve the situation regarding biodiversity and biomass of fish.

Question 3.10. Assessing interactions between habitat and biota (taxa and/or guilds)
Managing fisheries in Africa is challenged by a lack of reliable data concerning African fish and ecology. The specific composition of fish communities is mainly influenced by interactions between animals and their biotic and abiotic environment. Habitat is regarded as one of the key factors mediating these interactions. More knowledge is important to manage and monitor the health of ecosystems and the sustainability of fisheries, which in turn contributes to food security. There is a need to investigate impacts of habitat use and preferences on: spawning, larvae, juveniles and adults. This includes such parameters as lentic/lotic, temperature, oxygen concentration, and conductivity.

Question 3.11. Distinguishing Separate Anthropogenic Pressures on Fish Communities
Since the impacts of many, different pressures are correlated, future research needs to help us distinguish the impacts of individual pressures on fish taxa. How can we integrate research to distinguish the separate contributions of multiple pressures that degrade average fishery habitats: mining, deforestation, sedimentation, and river bank development?

Question 3.12. Hydrology, Climate Change, Dams and Fish Communities
How do the dynamics of surface waters affect fish communities in rivers and reservoirs? How have dams changed river dynamics over time? This is related to "environmental flows," i.e. a river should have sufficient water at all seasons to sustain fish communities. How does dam size (large vs small) affect fish communities? This relates to reservoir typology. It appears that fish can migrate over small dams but not large dams.

Question 3.13. Effects of invasive plants on fish diversity and productivity.
In many reservoir agriculture pollution and urban wastes (sewage) lead to important bloom of saprophytes and algae, how do this affect fish and fisheries? Can fish or BMI be the solution of this problem? .

Question 3.14. Human Impacts on Water Quantity and Quality in Reservoirs
Does sedimentation reduce reservoir volumes to critical extents, especially toward the end of the dry season, such that water quality declines and impacts fishery productivity?
Do excessive water withdrawals, due to mining and irrigation, reduce the available water volumes within reservoirs at the end of the dry season below thresholds critical to fish capacity to survive and reproduce in the wet season?

Question 3.15. Fishery productivity, adult fish size and egg production
Has human pressure, especially overfishing, so reduced average adult fish body size that fisheries productivity (of eggs and, ultimately, adults) requires extreme measures (fishing bans, aquaculture) to recover?

Question 3.16. Agricultural impacts on Fishery Productivity
Do artificial fertilizers in runoff so stimulate proliferation of aquatic macrophytes (e.g. *Ceratophyllum submersum*) that they severely impact the catchability of fish?
Do pesticides bio-accumulate in fish populations and degrade aquatic ecosystem productivity (disrupting the food web, trophic cascades)?

Question 3.17. What academic programs will professionalize the skills and knowledge needed to monitor water and fisheries at the higher levels that the SUSFISH project aims for?
In the University of Ouagadougou there is no diploma in limnology or related field like Aquatic resource monitoring. Therefore, it is important to think about how to implement a Master of limnology and Aquatic resource Monitoring in one of the Universities of Burkina.

1.2.2. Social Sciences

This section describes outstanding research questions that remain after completion of analysis of data by SUSFISH partners striving to address SUSFISH research questions related to the biophysical sciences, e.g. sociology, economics, politics and anthropology.

Table 4 – Key questions remaining for economic, social and political science research after SUSFISH is completed.

No.	Question
4.1	Is the concept of sustainability too vague to be useful for policy-driven research?
4.2	What are the challenges and opportunities for creating sustainable fisheries that are created by the history of unpredictable shifts in administrative responsibility at the National level of governance?
4.3	Does decentralization help or not in promoting the harmonization of different levels of governance as well as republican versus traditional institutions?
4.4	How can we assess the economic potential for local fisheries and aquaculture in Burkina Faso?
4.5	How can we shape future transdisciplinary research through better understanding and use of different forms of knowledge?
4.6	How can we assess the potential for fisheries management at the national level?
4.7	What methods are needed to assess how local knowledge influences the formulation and implementation of fishing regulations?
4.8	What different types of participatory processes could enhance policy and practice in fisheries management programs?
4.9	How do ethnicity, gender and socio-economic status influence the potential to participate in the formulation and implementation of fishery policy and practice?
4.10	How is communication influenced by the language used in different phases of action research?
4.11	How can we assess and describe different forms of corruption and their specific influences on fisheries management at different governance levels?

4.12	How is the potential for sustainable fisheries influenced by the combination of subsistence vs. commercial fishing?
4.13	What is the relationship between a fisherman's skill levels and the capacity of learn and apply new fishing practices?
4.14	What prevents the national level from better support for local fisheries management and from harmonizing fisheries policy and practice across all levels?

Question 4.1. Sustainability: is it too vague a goal to be useful?
In future research, how can we assess the diverse perspectives of different stakeholders on what "sustainability" is and how these different perspectives influence the chances of improving fisheries in BF? What does sustainability mean to us, to politicians, to local authorities, fishermen, sellers, etc.? the "sustainable livelihoods approach") is considering a multimodal capital,. How useful are our results if they are based on research that uncritically assumed a common understanding of sustainability (is e.g. environmental education/knowledge, which seems to be important for sustainability of fisheries and water management in BF)?

Question 4.2. Institutional Nomadism: what consequences for sustainable fisheries?
What are the consequences of the many institutional changes of fisheries authorities cited in the report for water quality and management? SUSFISH analysis shed light on these shifts and political practices but further research has to examine the consequences of abrupt and unpredictable cutting off of resources, staff turnovers, and loss of competences/experts' knowledge. Results showed the need to examine its direct impact on fisheries and water management as new people, new policies, revised or abandoned budget changes all create an atmosphere in which the bounds of responsibility become blurred.

Question 4.3. Harmonizing Multiple Levels of Governance: Does decentralization help or not? Two currents exist in BF: decentralization of Republican government and the resurgence of Traditional governance. How do these two currents influence the chances of establishing successful fisheries?
Importance of decentralization research:

1. Which aspects of decentralization processes are left aside in the current research? Should we focus on those in future or focus on the management of water resources only?
2. Which period(s) of decentralization is(are) relevant to our research?
3. Elite Capture – have decentralization and bottom-up processes been so often captured by elites that they are no longer effective because no one trusts them to work any more?

Question 4.4. Exploring the economic potential for local fisheries and aquaculture
How does development of aquaculture influence the re-establishment of natural fisheries in BF?

1. How strong is the demand of fish food growing in BF?

2. Under which conditions fish coming from aquaculture sector becomes affordable for Burkinabe people? What about price differences between fish species? Is there a cheapest? Imports from China or marine fish from W. African coast?
3. Why have fish farms/hatcheries, e.g. *Bagre*, fallen into disrepair and are not used at all?
4. Why have no marketing value-chains been set up such that fish and fish products can be sent in a safe (refrigerated) way from reservoir to consumer?
5. Is the availability of cheap imports undermining efforts to develop local fisheries and fish value chains just as has happened with "dumping" of cheap chicken products in Africa by Europe?
6. What about export of BF fish to Mali and Niger?
7. What means are in use to raise the values of fish and fish products (fillet, dry fish, smoked fish, fried fish, frozen fish) in value chains? For example, they have value chains for green beans exported to Europe (*Chef du Canton* near Lake Bam).

Question 4.5. Future transdisciplinary research: understanding and using different forms of knowledge:
There is a critical need to assess the implications of using different forms of knowledge for education and development of curricula, and especially for knowledge elicitation in socio-economic research.
In (our) transcultural and transdisciplinary research we depend on key informants and interpreters.

1. How can we assess their knowledge, relations and personal agenda?
2. What should we consider as important factors for this kind of cooperation when planning research?
3. What do they need in order to help us with understanding and the interpretation of findings?
4. What should they learn about our research?
5. How should we interpret our findings about fishermen's knowledge: „most fishermen declared not to know anything about the ecology of the new species. Those who said they know can not explain..."?
6. How important are language problems for this outcome?
7. How can we ensure that our key informants can express themselves in all phases of research: agenda formulation, knowledge elicitation, and analysis?
8. What are methodological implications on answering questions 1-7?

Question 4.6. Future Direction of Fisheries Management at the National Level

1. Which data about the General Directorate for Fisheries Resources is required to assess the potential for fisheries policy formulation and management, especially with regard to development of management institutions that function at and across all levels of governance?
2. What are the respective groups of actors and their group-specific information needs concerning water management responsibilities, etc., that overlap in the policy arena overseen by the GDFR?

3. How could this information be edited, adapted, that it meets the communicative needs of the addressees? Especially as we know that language barriers lead to distrust and reinforce resistance to regulations.
4. Which additional genres of communication besides policy note and research paper should be assessed?

Question 4.7. Local knowledge and formulating and implementing fishing regulations

1. How can we assess the experiences of local and governmental actors in implementing common water and fish resource management regulations?
2. Are our methods to elicit knowledge appropriate to understand local strategies of natural resource managements/protection of resources? Obviously we did not learn enough about the degree of local people's concern(s) and the indicators for "threat" they identified

Question 4.8. What participatory processes could enhance fisheries management programs?

1. Which participatory methods available (ranking, mapping, village walks, Venn diagrams, mind mapping, rich pictures,..). or action research and collaborative learning might be applied in future research?.
2. How to ensure inclusion of critical "end" stage processes like "Phasing out", e.g. as research has begun in the community, the potential for conflict must be lowered by allowing the experiences of stakeholders to be included, debated, and joint decisions reached about how to address new challenges at this stage

Question 4.9. How do ethnicity, gender and socio-economic status influence the potential to participate in the formulation and implementation of fishery policy and practice?
Do real barriers to participation exist, and, if so, how do they affect fisheries? For example, involvement of women or strangers differs from region to region.

Question 4.10. How is communication influenced by the language used in different phases of action research?
In Burkina Faso what language(s) should be used for a. administration, b. research (knowledge elicitation), c. education and information dissemination, and is there no answer that is general to all of Burkina Faso but specific to different ethnic groups?
What languages facilitate a. negotiation, b. knowledge transfer, translation, interpretation and integration?

Question 4.11. How can we assess and describe different forms of corruption and their specific influences on fisheries management at different governance levels?
To what extent does corruption influence management of fisheries and water bodies in BF? For example, government officials in the Ministry of Environment have been observed to sell licenses and keep money for themselves. This accords with the observations of Jean Pierre Olivier de Sardan, an anthropologist in Niamey, on corruption at different levels of government.

Question 4.12. How is the potential for sustainable fisheries influenced by the combination of subsistence vs. commercial fishing?

1. To what extent do fisheries contribute to livelihoods based mostly on subsistence agriculture and to what extent do purely commercial fisheries influence livelihoods?
2. What does 'subsistence' mean for local people in BF, and how is it actualized? Regarding the subsistence concept, it not only contributes to income, but it influences management of natural resources, fisheries.

Question 4.13. What relates the average level of fishing skill with the potential for capacity building for better fishery practices?
Except on (very) large reservoirs; fishermen are not professionals. They are firstly farmers who diversify their activities, but these skills are not heritable, so

1. From whom do non-professional fishermen learn when there are few if any professional agents or NGOs to teach and advise them?
2. Do low skill levels of non-professional fishermen hamper abilities to learn better fishing methods and to learn and obey fishing regulations?

Question 4.14. What prevents the national level from better support for local fisheries management and from harmonizing fisheries policy and practice across all levels?

1. We observed failure of federal agents to enforce rules or advise in fisheries development at the local level, especially for small reservoirs. Is insufficient 'political commitment' to develop the rural fisheries-sector because most fisheries resources are scattered among too many very small reservoirs?
2. Is failure to harmonize national, regional and local governance institutions aggravated by distrust at local levels for national law and administration sustained since early in the history of French colonial administration.

Section 2. Implications of SUSFISH Research for Science and Practice

The outstanding questions described in Section 1.2 offer ample opportunities for research to expand the BF fisheries knowledge base in directions most useful to the creation and enforcement of policy and practice. However, these research questions can be expanded and more sharply defined by exploring expert opinion to see what are likely paths on which BF fisheries might develop. SUSFISH partners used group focus sessions to develop and elaborate a set of scenarios of future fishery trajectories. Looking at only a subset of the most intriguing scenarios, Section 2.1 describes the details, e.g. storyline narrative, relevant factors and their relationships, that are critical to understanding how these scenarios might unfold. Section 2.2 describes how SUSFISH partners used conceptual mapping exercises to extend this line of inquiry. This was done by developing two-dimensional maps that graphically illustrated diverse ways that the critical factors might be related, e.g. chains, webs, feedback loops. Both the scenarios and the conceptual maps offer opportunities to further refine the research questions of future projects exploring paths to develop BF fisheries and increase food security through fish culture.

2.1. Scenarios that Merit Further Scrutiny

SUSFISH has generated a great deal of new knowledge about the potential to develop and manage sustainable fisheries in Burkina Faso, both as facts and concepts (Lessons Learned) as well as identifying the most critical entry points for future research (Remaining Questions). However, neither facts nor questions are sufficient to fully explore the implications of the knowledge gained, especially in terms of the dynamic complexity of a social-ecological system. How might events unfold under different sets of conditions? What trends have been critical to the present state of affairs, and how might these trends change over time, shifting the probabilities that various strategies and policies might fail or succeed? Work Package 8 staff opened the door to the dynamic implications of what has been learned in SUSFISH by offering the partners opportunities to develop scenarios of future development of fisheries that identify and describe key trends and developments that need further attention.

Scenarios can be used to guide the development of future research agendas because they incorporate and integrate into one storyline (sometimes with multiple threads) a number of factors that merit further investigation: trends, scenarios and the interactions between factors that influence the dynamics of said trends and scenarios. As such scenarios can weave together Lessons Learned and Important Remaining Questions into synthetic wholes that invite exploration of the relationships between the Lessons and the Questions as well as their component factors.

Methods: Pursuant to the overall goal of developing an overview of SUSFISH findings, WP8 staff worked to assemble and integrate information inputs from SUSFISH partners and outside experts. First, a literature survey (see Appendix) developed a background database on fishery sustainability factors evident in both natural and social science literature. This background information was used to design and organize a week of meetings in November, 2013 in Ouagadougou to elicit expert knowledge about both natural and social factors that

influence fisheries sustainability in Burkina Faso. Two workshops were conducted in series to provide a database for developing a synthetic overview and systems analysis of the potential for sustainable fisheries in Burkina Faso. This potential will be assessed based on systems analysis of interactions within and between bio-physical and socio-cultural domains that are key to fisheries management. These meetings did so by convening natural science project partners to consider bio-physical factors and their interactions. A second meeting convened social science project partners to consider socio-cultural factors and their interactions.

In preparation for this series of meetings, in early November WP8 staff met with the Project leader and two Burkina graduate students to develop and apply a questionnaire that helps identify scenarios by which sustainability is strengthened or weakened, and factors and their interactions that are critical to those scenarios. The questionnaire offered each partner or outside expert and opportunity to identify scenarios that trace future developments that may involve increasing or decreasing sustainability of Burkina Faso fisheries. They could do so describing: 1. What is a trend (historical, statistical) that is significant to fishery sustainability over the long-term?, 2. What is a brief (less than 5 sentences) scenario that summarizes the main developments that help explain or elucidate this trend and its consequences, 3. What are the factors that require research in order to understand each scenario and its dynamics in better detail?

This questionnaire was sent to all project partners for their input. This preparatory survey and the Ouagadougou workshops generated some fourteen scenarios (see below for titles and the Appendix for details) that emerge and extrapolate from current understanding based on biophysical science and the social, economic and political sciences.

These initial draft scenarios postulate fishery productivity declines because of:

1. Societal metabolism, e.g. processing of energy and materials for domestic and economic reasons, and use of shore habitat increase the sediment load in surface runoff (sedimentation) and gradually fill reservoir benthic zones, reducing reservoir volume, and lowering the quantity and quality of water in the water column and aquatic habitats used by fish and other fauna for food, shelter and reproduction.

2. Overfishing, especially of large, mature adult fish, reduces average adult fish size, and, hence the average fecundity of adult fish, thereby reducing production of fish eggs, larvae, fry and juveniles.

3. Fish community metabolism and reproduction decline because average fishery habitats are degraded by mining, deforestation, sedimentation, and river bank development.

4. Excessive inputs of artificial fertilizers may stimulate the proliferation of aquatic macrophytes (e.g. *Ceratophyllum submersum* in the Boura reservoir), thereby physically blocking boats and nets and reducing the catchability of fish (among other problems).

5. Pesticides bio-accumulate in fish populations and degrade aquatic ecosystem productivity (disrupting the food web and trophic cascades) and the reproductive efficiency and growth of (commercial) fishes remain unknown.

6. Anthropogenic pressures (societal metabolism and shoreline habitat use) increase the loading of surface water nutrient inputs to aquatic biotopes, shifting the dominance of phytoplankton communities toward cyanobacterial assemblages that prevail in reservoir surface waters and reduce the availability of phytoplankton palatable to fish.

7. Excessive water withdrawals, due to mining among other activities, reduces the available water volumes within reservoirs at the end of the dry season decline below thresholds critical to fish capacity to survive and reproduce in the wet season.

8. Artificialization of hydrographic networks: Cascades of infrastructures along hydrographic networks and the absence of by-passes for fish disrupt the hydrographic connectivity during the flooding period and do not allow fish to migrate upstream and then (re)colonize lakes and reservoirs.

9. Reservoir volumes decline due to insufficient protection and maintenance of reservoir infrastructures (dikes, spillways,...), especially if crocodiles' chambers excavated from dikes thereby weaken them and make them more vulnerable to hydrological disturbances (excessive flash flood).

10. Rising importance of International Fish Markets and Fish-Products Importations to BF. The low prices of imported fish products do not allow the exploitation of local fish populations to become a sustainable activity. Lack of profitability because of market competition with imported fish-products proves to be too high a hurdle for the initial investments in the infrastructure and training necessary to make inland fisheries a mature industry.

11.Low fisheries skills of non-professional fishermen. Except on (very) large reservoirs; fishermen are not professionals. These stakeholders are firstly farmers who diversify their activities – and income's sources – in fishing (all year round or seasonally). Fisheries activity is not patrimonial (as farming could be) and there is no real heritability of this skill.

12. Insufficient 'Political commitment' to develop the rural fisheries-sector because most fisheries resources are scattered among too many very small reservoirs.

13. Increasing populations of alien fish species cause indigenous species to decline. Sustained invasion and subsequent reproductive success of alien fish species causes their resident populations to grow. As the alien fish species outcompete indigenous species for food resources, the latter populations decline.

14. Failure of natural resource management accompanied by distrust at local levels for national law and administration sustained since early in French colonial administration.

2.1.1. Biophysical Sciences

Of the fourteen initial draft scenarios, one scenario ostensibly anchored in biophysical science rapidly comes to the mind of any observer of fisheries in Burkina Faso. In most markets the size of locally caught fish is strikingly small, and there is a vast difference in fish size between fish caught in regulated versus unregulated aquatic habitats. Adult fish size correlates with egg production, and, ultimately, the productivity of the entire fishery. Since this relationship is non-linear, meaning there is often a threshold below which egg production is orders of magnitude below its potential, the question arises as to whether the fisheries in Burkina Faso are caught in a trap, boxed in in a zone of low productivity below the threshold, and that it cannot be escaped without massive intervention to allow fish populations to recover. This is the scenario that SUSFISH partners chose to explore in more detail, as described below.

2.1.1.1. Process or Trend influencing Fishery Sustainability:

Fish productivity declines as average adult fish size declines.

2.11.2. Key Words: Fecundity, Egg production, Fish Size,

2.1.1.3. Scenario showing how sustainability is influenced:

Title: Fishery policy restores fishery productivity by reversing the declining trend of adult fish size.

Over the coming years fishery management becomes sustainable for two reasons: A. fish managers can lower fishing pressure by controlling fish net mesh size and B. because scientists discover for each economic fish species what its optimal reproductive adult size is, providing guidelines for policies setting mesh size and monitoring the timing, duration and intensity of fishing efforts. This combination results in a reinforcing loop in which each fish species becomes more productive as average adult fish size increases beyond thresholds where egg production increases exponentially.

2.1.1.4. Important factors involved in this scenario:

<u>How to read and understand the Hierarchical List of Critical Factors:</u> The factors of concern to this scenario have been listed in a hierarchical order that can be understood as follows. The most fundamental factors are placed the furthest to the left in the First Tier, and as one's eye moves to the right the degree of specificity increases as each succeeding factor in the next lower tier is described. This "lower" factor supports the next higher factor and, ultimately, the fundamental factor in the first tier. Counter-intuitively, the higher the tier number, the more specific and supportive it is of factors from tiers of lower numbers. For

example at the top or start of the Hierarchical List 1 below, the most fundamental factor is "*Fish production rate*", which can be further understood by the second tier of supporting factors, e.g. *Egg Production rate*", "*Number of Juvenile Fish*", "*Number of Adult Fish*", and "*Water quality*." Each factor in the second tier is further explained by more specific factors in the Third Tier. Therefore, *Egg production rate* is further explained by *Average Adult Fish Size, Egg Survival Rate, Arrival Rate of Mature Fish to Spawning Grounds,* and *Pattern of Reservoir Filling*. This hierarchical ordering continues, including a fourth and a fifth tier of factors.

The hierarchical organization offers a basis for systemic comparison of factors that influence the dynamics of a scenario. It does this by showing the dependence of factors, most directly within each line from most to least fundamental factor, but also indirectly by suggesting potential relations between factors across levels, e.g. relations between all the factors in the second tier. This form of knowledge elicitation and recording established the basis for a more thorough and comprehensive systems analysis, which would explore more complex interactions, e.g. webs of interactions and feedback loops that involve factors at different levels of the hierarchy. The SUSFISH project has established that basis for more comprehensive overviews with this initial system overview based on hierarchical structure.

Hierarchical List 1: Critical Factors for Biophysical Science Scenario

- Fish production rate
  - Egg production rate (Fecundity), Spawning rate (*frayage)*,
    - Average Adult Fish Size
    - Egg survival rate
      - Egg predation rate,
      - Disease incidence,
      - Water quality
        - Oxygen Concentration, Temperature, pH, Chemicals.
    - Arrival rate of mature fish to spawning grounds
    - Pattern of reservoir filling (1 *nuit* ❼ poor spawning vs. 2 *mois* ❼ good sp.)
      - Filling rate
        - Rainfall pattern (intensity, spatio-temporal variation, seasonal)
      - Availability of Habitat Services
        - Habitat area (spatial mosaic), habitat quality
  - Number of Juvenile Fish
    - Recruitment Rate
      - Nursery habitat area and structural complexity
      - Growth rate from fry to juvenile
    - Predation pressure
      - Density of Birds, frogs, fish,
  - Number of Adult Fish
    - Recruitment Rate
      - Habitat area and quality:
      - Growth rate from juvenile to adult

- Availability of fish food
- Fitness of Adult Fish
  - Prey availability (macro-invertebrates, etc.)
  - Disease incidence
  - Condition Factor (Weight-to-Length ratio)
  - Water Quality (Temperature, pH, Oxygen, Chemicals)
- Population mobility (rates of immigration and emigration (fish number arriving from outside the reservoir or leaving)
  - Dams (presence, condition), Fish ladders (presence, condition)
  - Fishing practices in the hydrological network
    - Use of nets as a barrage across the entire river
    - Fishing using toxic chemicals
  - Length of dry period without water in reservoir
- Water quality
  - Water Quality Variability
    - Reservoir turnover rate (*Polymyctic* – multiple mixing)
      - Reservoir basin bathymetry (depth, shape)
    - Seasonal variation in shape and depth
      - Dry-down rate as dry season progresses
  - Water Quality Intensity
    - Concentration of Toxins,
      - Pesticide and herbicide use by farmers
      - Heavy Metal Concentration (Hg, Cyanide)
      - Acids and Solvents
    - Oxygen concentration,
      - Fertilizer use (type and intensity), Algal growth rate,
      - Proportion of Cyanobacteria in the algal assemblage
    - Turbidity
      - Sedimentation rate,
      - Littoral macrophytes (area, density) esp. grasses
      - Phytoplankton productivity
- Fishing pressure (intensity and effectiveness of fishing efforts),
  - Fish density
    - Number of Adult Fish
  - Effectiveness of fishing practices
    - Water volume
    - Legality of Fishing Method (ratio legal / illegal)
    - Fish Nets (Mesh Size, number, length)
    - Long-lines (number, interval between hooks, length)
    - Traps (number and positioning on the river cross-section)
    - Duration of Fishing Season
  - Number of Fishing Man-days
  - Availability of fishing skills and knowledge
    - Availability of expert advice
      - Organizations Fishermen Associations, NGOs, Ministries)
      - Local Community

- Amount of professional fishing experience (fishing years) in the local community
  - Average age of fishermen
  - Number of old (wise) fishermen
    - Out migration rate of fishermen to
      - Other fisheries in Burkina Faso
      - Gold mines in Burkina and the region
      - Dakar, Lagos, Abidjan
- Economic pressure on fishermen to *fish*
  - Economic pressure from Socio-Cultural events and ceremonies
    - Events that require payments (weddings, Christmas, etc.)
  - Demand for Fish
    - Domestic fish economy
      - Ratio of domestic production to consumption rates
        - Fish production rates
          - Capture Fisheries
          - Aquaculture
      - Importation rate of fish from outside Burkina Faso
    - Fish Consumption Preferences
      - Average quality of fish consumed
      - Types of fish preferred (size, species, processed or not)
  - Income from terrestrial farming, Income from livestock,
  - Income from Aquaculture (*shifts fisherman from catch to fish farming*)
  - Price of Protein,
    - Fish Price, Meat Price, Ratio Fish/Meat prices
  - Cost of Living
- Mining activities impact on local economies

Effectiveness of Governance

- Effectiveness of Republican Governance
  - Effectiveness of Government Institutions
    - International Pressure (Govt, and NGOs, Banks)
    - Policies for management (administrative code)
      - Existence
      - Acceptance by practitioners and resource users
        - Awareness of policy
        - Legitimation through participation
    - Legislation
      - Existence
      - Implementing Agencies (fisheries dept)
        - Feedback between policy formulation and implementation
  - Fish Rangers (Foresters),
    - Days of ranger oversight,
    - Susceptibility of rangers to bribes (*soudoyer* – Corruption),
      - Salary of Rangers,
    - Effective oversight of rangers

Belief in Government
Stability of Government Hierarchy (shifting and unpredictable Ministry responsibilities)
Effectiveness of Traditional Authority,
Faith in *Tengsoba*, Fear of the Gods, Holy Crocodiles
Effectiveness of Fishermen Associations
Present or not present, Degree of organization

5. Relations between factors that influence this scenario:		
Factors involved:	How they interact:	Results
Egg production rate, Average Adult Fish Size	Exponential increase in egg production above species specific size threshold	Large fish are orders of magnitude more productive than small fish
Number Fish, Migration Rate (fish number arriving from outside the reservoir) Dams (presence, condition),	Some dams are in poor condition and allow fish to migrate around them.	Most reservoirs completely dry out and fishery totally depends on migration from the outside.
Number of Fishermen, use of chemical poisons, Fish Net Mesh Size, Duration of Fishing Season	Increasing of fishermen reinforce the use of illegal fishing methods	The decline in catch volume
Fish density, Water volume	The raining season increase available food and floodplain	Increasing of fish reproduction and fish migration

2.2.1 Social, Economic and Political Sciences

One scenario related mostly to the non-biophysical sciences seemed to occupy a central position that linked it with most other scenarios of BF fishery development. That scenario, described below, examines the factors and relationships that inhibit communication and trust in governance between different levels within government as well as between those in government and those outside, e.g. NGOs, business (fishermen and fish mongers), and concerned citizens.

2.2.1.1. Process or Trend influencing Fishery Sustainability:
Failure of natural resource management accompanied by distrust at local levels for national law and administration sustained since early in French colonial administration.

2.2.1.2. Key Words: Governance, Scale, Natural Resources, Colonial rule

2.2.1.3. Scenario showing how sustainability is influenced
Title: Multi-level Governance related to natural resource management at the local level

Failure of natural resource management sustained since early in French colonial administration that unfolded over the past 130 years in response to processes at different levels. Local Administration (before 1885), Colonial administration (1920 – 1960), National administration (1960 to present). The Local level has exhibited declining effectiveness of local resource management. This decline is revealed by a shift from a semi-effective local-level community organization to more individual decisions over the past two decades.

Modern republican governance does not work well enough at the local level. The traditional organization is in place at the local level, e.g. There are different groups involved in managing fisheries. However, family ties to those in traditional power positions increasingly determine who assumes power within the republican governance structure, e.g. The president of an association is the brother of the local chief. So the local chief has increasing influence over modern organization. This "takeover" like *Elite Capture* has accelerated since the national policy of decentralization started. Part of the problem is also of representation within any of the local organizations: whom does the brother of the local chief really represent, and does that change his effectiveness in contributing to management? This ambiguity damages the process of *legitimation of power* of the local level: who is the "owner" of local resources?
This trend of increasingly using family ties rather than expertise to determine who gains power in modern governance can lower the collective expertise of governance. It also concerns equity within the community. If you do not feel responsible to represent certain groups, then power "unnaturally" concentrates only to certain groups (clans, families). This power shift is accompanied by a shift of financial resources, because the powerful can increasingly divert funds for government projects to their own family finances.
T*ransparency* also suffers when decisions (financial or governance) are made more within families than in the "open air" of public discussion for government. As transparency declines and suspicions mount that the system only works for a few (the elite have captured

the decentralization process), then people will ignore the governance process and act individually, hoping no one will notice or take action.

2.2.1.4. Important factors involved in this scenario:

Hierarchical List 2: Critical Factors for Social, Economic and Political Science Scenario

Republican Government related to water management
- Administration
  - Policy - Develop, implement and monitor implementation and impacts
    - National
    - Sectoral
    - Regional
    - Local (reservoir or lake)
  - Strategy
    - National
    - Sectoral
- Legislation
  - National
    - Law (Acts)
    - Ordinances (Assembly National)
    - Decrees (President)
    - *Arrêtés* [1](Minister, Mayors)
    - Decisions (Directors)
  - International
    - Conventions
    - Accords, Pacts
- Institutions (organizational structure)

[1]

Governance Institutions that work at the local Level (even if based at higher levels)
- Republican Government
  - CLE (*Committée Local de l'Eau*)
  - Fishermen's Associations
    - Groupments,
      - *Groupment des pecheurs* a Kongoussi
    - Union (national, provincial level)
  - Foresters
  - Assoc. of Women who process fish
  - *Comité du Gestion Périmètre Halieutique d'Intérêt Economique*
    - 9 in Burkina Faso, for all organizations interested in water but only 3 operational committees so far.

[1] un *arrêté* est une décision exécutoire à portée générale ou individuelle émanant d'un ou plusieurs ministres (*arrêté* ministériel ou interministériel).Translation: a *arrêté* is an executive decision with binding consequences in general or for individuals that was issued by one of more ministries of the national government's administration.

Traditional Government

Conflicting processes: *legitimation of power* and *legality*
- Damage to legitimation of power within republican organizations
  - Exclusion of marginal groups
    - Network Analysis of power relations within the local community
    - Membership within republican organizations
      - Balancing interests between men and women
    - Women excluded from information access
      - Do not know that it is illegal to buy fish that are too small
  - Poor compliance with rules of governing organizations
    - Election organization (every 2 years)
    - Meetings (do not meet often enough to be effective)
      - CLE is often too big to make it easy to assemble)
    - No accountability (no feedback to members, no transparency)
      - Lack of trust
        - Why pay when I cannot see the advantage
        - Why pay when the money goes to people I do not trust
    - Indigenous resistance to "foreign" ideas
      - GERES – experience of dominating foreign administration
      - Foreign ideas do not "taste good."
      - Confusing shifts back and forth as to what is recommended:
        - Foreigners told them to cut the trees at Lake Bam, now they say we should grow them.
  - Free rider problem: why pay for a public good available for "free"
    - My ancestors did not have to pay, why should I?
    - Failure to pay tax or dues related to fishing or membership in organization.

  - Resistance to modern rules that depart from tradition
    - Refuse to abandon practices deemed "illegal " by modern rules
      - Use of forbidden fishing gear
        - Nets with mesh dimension < 35mm
      - Fishing without a license
      - Selling fishing rights without authority
        - Fishermen pay for right to take all fish in a reservoir when actually the seller has no right.

  - Failure to enforce the law
    - Foresters are not activated by a specific "project" or initiative that mandates that they go and monitor fishermen. Without specific mandates, they ignore the situation.
      - Foresters do not monitor who fishes (or educate people locally)
        - Mali fishermen pay directly to local community (5K per fisherman per month in addition to some fish) as

opposed to 8K per year to the republican government. (see p156 Raymond Ouedraogo Dissertation)

Foresters influenced by their "Local Guides"
- Foresters nominated for their jobs based on expertise, but they operate in cooperation with a "Local Guide."
  - LG are nominated locally.
- Local Guides sometimes organize resistance that nullifies enforcement.

Lack of resources to support enforcement
- Funding
- Training or Expertise
- Power to enforce the law

New rules or law cannot displace the traditional rules
- In the minds of local resource users (fishermen, hunters)
  - See above about resistance to new laws
  - Laws conflict with Traditional Practices, e.g. Use of fetishes (Voudou)
    - Local people chased out the foresters and police from Mousoudougou after they tried to fine a hunter for catching a rabbit without a license, which actually was legal, so this was **an abuse of power.**

- In the minds of the forester
  - Foresters may not agree with new law
  - Foresters not willing to go against majority opinion.
  - If the Forester does not understand local traditions, even non-verbally they can communicate this lack of understanding and create tension in the community. This can easily occur when foresters come from elsewhere.

Commodification of fish
- New trend from subsistence to commercialization creates a momentum that is hard to counteract by enforcing the law.
  - Trend runs counter to traditional governance that co-evolved with subsistence fishing, which was a minority, rather than the majority now that will do anything to gain money in an expanding industry.
- Poverty of fishermen obliges them to fish *by any means necessary.*
  - Population dynamics reinforce the economic pressure to gain money *by any means*
- Trend expands the role of women in fish processing.

Conflict between Republican laws and Traditional rule
- When confusion exists between Republican and Traditional rules, then people will usually resort to the Traditional.

Local conceptions of
Natural resources (Water, Fish, etc.)
Power
Network of relationships

2.3. Systems Analysis of Behavior Patterns Critical to Sustainability

While previous sections if this report actually do constitute systems analysis by describing a hierarchical structure of relations between critical variables, there is ample potential to extend that systems analysis using other techniques, such as conceptual mapping. Insufficient resources of time and funding prevented WP8 staff from working long enough (months to years) with a wide enough circle of expert opinion to generate detailed conceptual maps abetted by systems analysis that uncovers previously unappreciated patterns of causation. That level of effort would have required working with all SUSFISH partners in addition to some outside experts and key stakeholders to elaborate on the basic systems analysis established through scenario development (Section 2.2). However, with the help of systems modeling expert, Piotr Magnuszewksi, from the Center for Systems Solutions, WP8 staff worked with several SUSFISH research partners, to develop a systems analysis through conceptual mapping of several scenarios. These exercises serve to illustrate the potential for conceptual mapping to help stakeholders identify potential critical relationships between factors that might help explain the dynamics of concern in a trend and/or scenario. Under the best of circumstances, such exercises would continue for a prolonged series of meetings over months to refine the maps by iteratively challenging and revising the map's hypothetical structure using new data from literature, expert opinion, or current unpublished research results. To try to illustrate the potential of conceptual mapping, we met several times in Spring 2014 and confined our efforts to two sets of scenarios: a biophysical science set based on scenarios 1-4 and a social science set of scenarios based on scenarios 12 and 14 (see Appendix).

<u>How to read a concept map made with Cmap software</u>:

Cmaps software allows one to generate conceptual maps wherein the concepts are linked by relationships that are verbally described by one to many words. This permits one to "read" the graphic map as a group of related sentences. For better clarity in this Report, in the text describing conceptual maps concepts are denoted in *italic font* while the verbs are denoted in normal font. One example of a sentence can be found in the upper right corner of Figure 1 below. *Sedimentation* reduces *Area and duration of flooding for fish nursery habitats,* which affects the *Fish Productivity,* which affects *Fish Population* which affects *Fish Yield.* By using words to complement the graphic depiction of relations, it is not only easier and faster at the outset to comprehend the individual ideas and the collective concept of the map, but, if one returns to the diagram after a prolonged period, it is also much easier to relearn the diagram and resume work on it. Cmaps is currently at the frontier of software to provide such graphic tools to describe a set of related hypotheses about collective causation in complex systems.

2.3.1. Systems analysis of the biophysical sciences set of scenarios

The suspicion that different scenarios do not stand alone but are related drives the search to identify those relationships, and Figure 1 reveals immediately how easy it is to link scenarios 1 through 4. All 4 scenarios are involved in a web of relationships that affect *Fish Productivity* and *Fish Yield*. Scenario 1 (Sedimentation) involves factors that influence *Fish Productivity*, e.g. *Ambient Water Temperature* and *Area and duration of flooding for fish*

habitats. Scenario 2 (Fish Size/Egg Production) involves the hub of relations that influence both productivity and yield. Scenario 3 (Fish productivity/Habitat) posits a direct relationship between habitat quality and productivity. Scenario 4 (Macrophyte proliferation) posits a relationship between agricultural fertilizer inputs, macrophyte density in the littoral zone, and *fish catchability*, which directly affects *Fish Yield*.

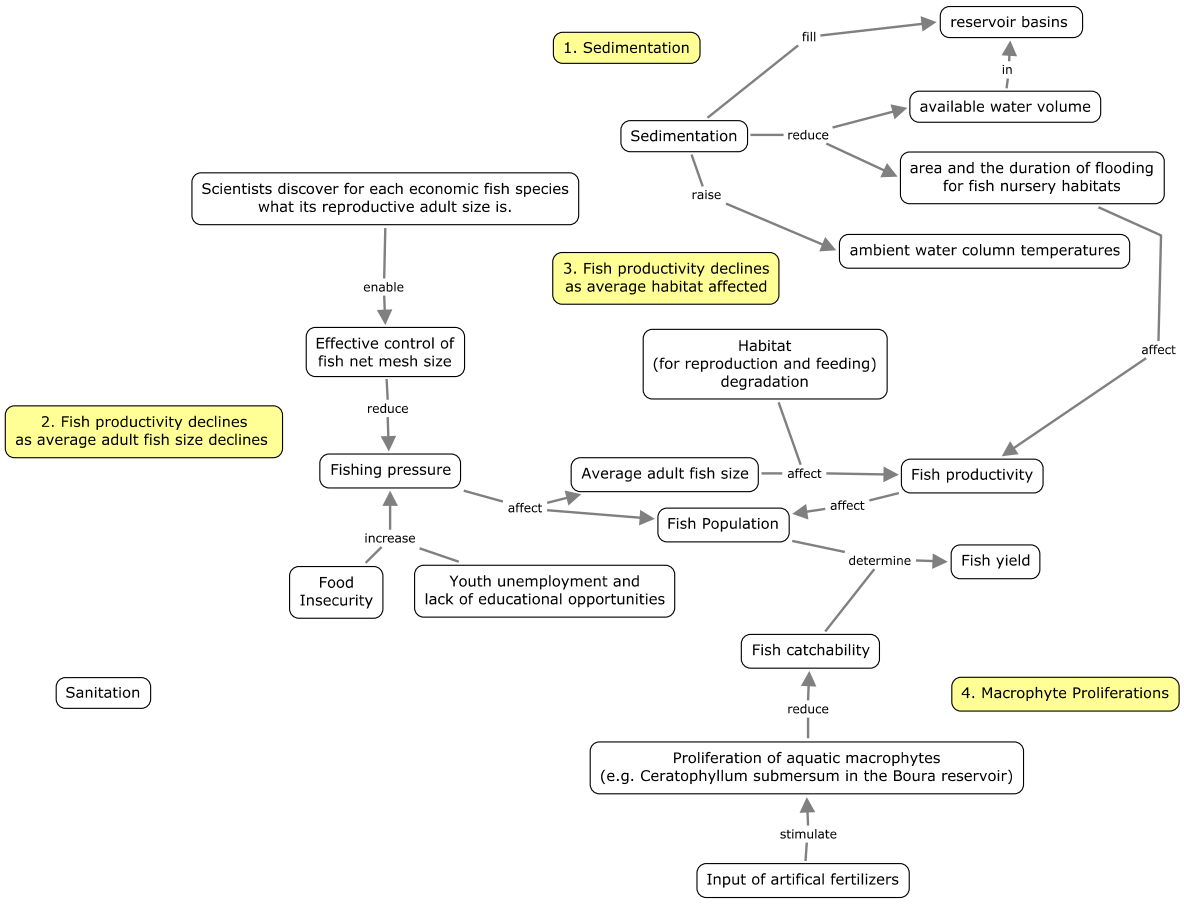
The conceptual map in Figure 1 is a graphic picture of a hypothetical set of relationships. Each set of relationships posited under each scenario is not very complicated as graphed, but the overall map may appear complex, because most people document complexity with the length of lists of factors and/or verbal descriptions of relationships between the factors. It still is a rare challenge for most people, even scientists, to view and comprehend the constellation of all the relationships in a system. The art of interpreting two-dimensional maps of linked hypothetical relationships is still relatively new. Suffice it to say, that with increasing inputs of data over time, each scenario could eventually be described by a conceptual map that is far more complex in structure or by a "family" set of maps that are related or linked by common variables. But Figure 1 is the product of a brief, experimental probe in mapping by SUSFISH partners that aims for a simpler goal. It clearly shows that scenarios are very likely related and that the relationships and key common variables have potential to inform the research agenda of future projects related to water and fish science in Burkina Faso.

2.3.2 Systems analysis of the social, economic and political sciences set of scenarios

Research based on social, economic and/or political science in SUSFISH has generated a considerable number of lessons learned (Table 2), important follow-up questions (Table 4) and scenarios richly detailed with a daunting number of candidate factors (Hierarchical List 2). As previously noted, the hierarchical structure of relations between key factors does constitute the foundation of a systems analysis of social, economic and political variables that influence fishery sustainability. But conceptual mapping offers opportunities to extend that analysis to explore more complex causal structures, e.g. webs and feedback loops. WP8 staff met several times in Spring 2014 under the direction of Piotr Magnuszewski to create conceptual maps based on two social science scenarios: 12 and 14 (page ??).

Figure 2 summarizes those modeling efforts and reveals a number of intriguing feedback loops, i.e. rings of factors that are linked in a circle of causation. These structural patterns are hypothetical, and their value lies in defining reinforcing patterns of causation that are hard to identify because most people think linearly but are worthy of further examination. On the broadest level, this experimental modeling session posited a loop as follows: *Failure of natural resource management* adds to *Governance Challenges* that undermine our *Capacity to implement (enforce) laws* which leads to more *Failure of natural resource management.*

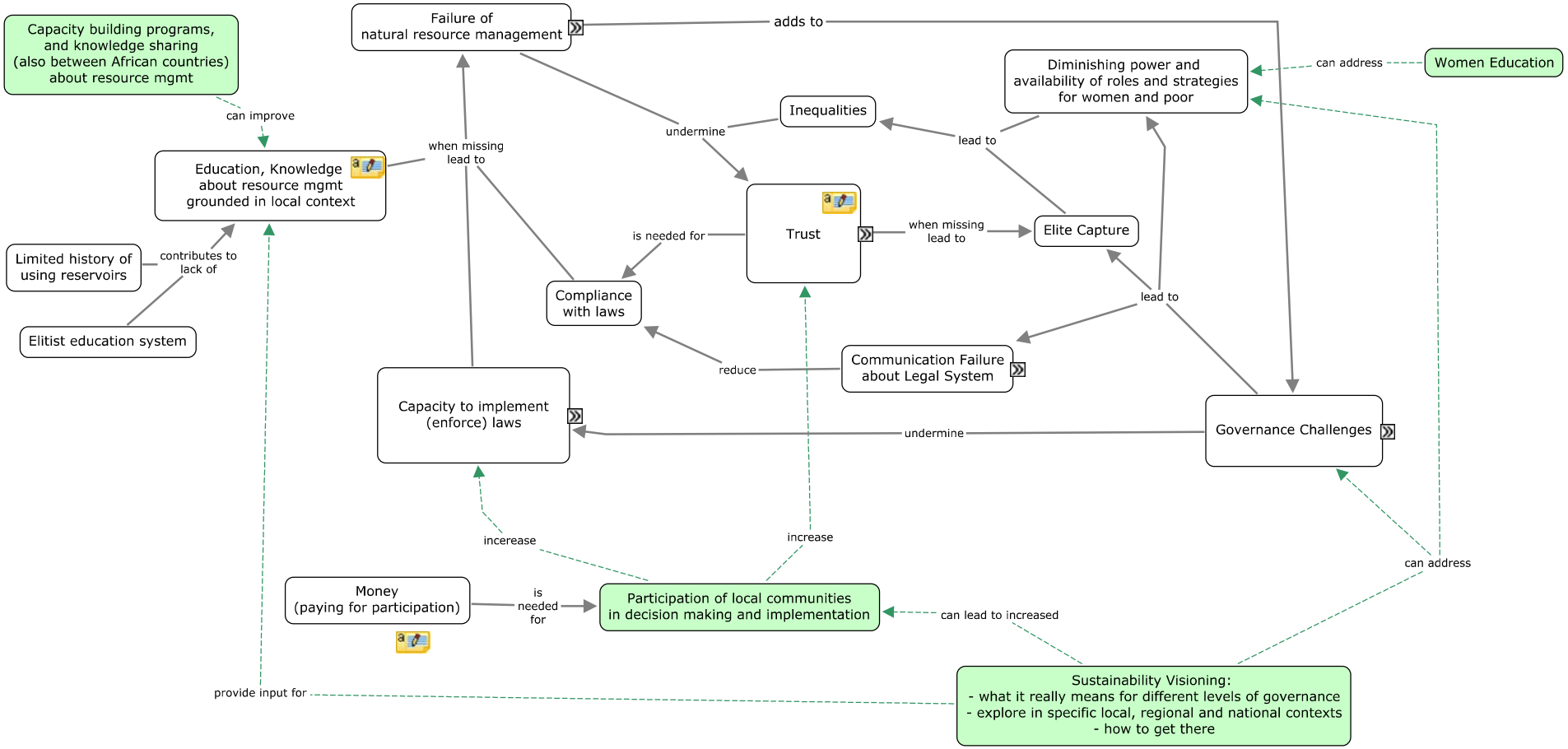
Figure 1 – Concept Map of Key Biophysical Processes Affecting Fishery Sustainability in BF



Several minor loops work within this broader loop. *Governance Challenges*, which are examined in more detail below (see Figure 3), lead to *Communication failure about the legal system* which reduce *Compliance with laws* which hinder our *Capacity to implement (enforce) laws* which leads to more *Failure of natural resource management.* Furthermore, *Governance Challenges* can lead to *Elite Capture* of participatory bottom up processes, which leads to more *Inequality* in power sharing, which undermines *Trust*, and, hence, *Compliance with laws* which leads to more *Failure of natural resource management*. *Governance Challenges* can lead to *Diminishing power and availability of roles and strategies for women and poor* which leads to more *Inequality,* lowers *Trust, Compliance, thereby* increasing *Failure of natural resource management.* Finally, this failure itself undermines *Trust,* leading to lower *Compliance* and more *Failure*.

In summary, *Failure of natural resource management*, which consists of water pollution, overfishing, water overconsumption, and erosion leading to sedimentation, can be analyzed not as one or several single chains of causes but as a set of loops that reinforce and augment

Figure 2 – Concept Map of Key Social Processes Affecting Fishery Sustainability in BF



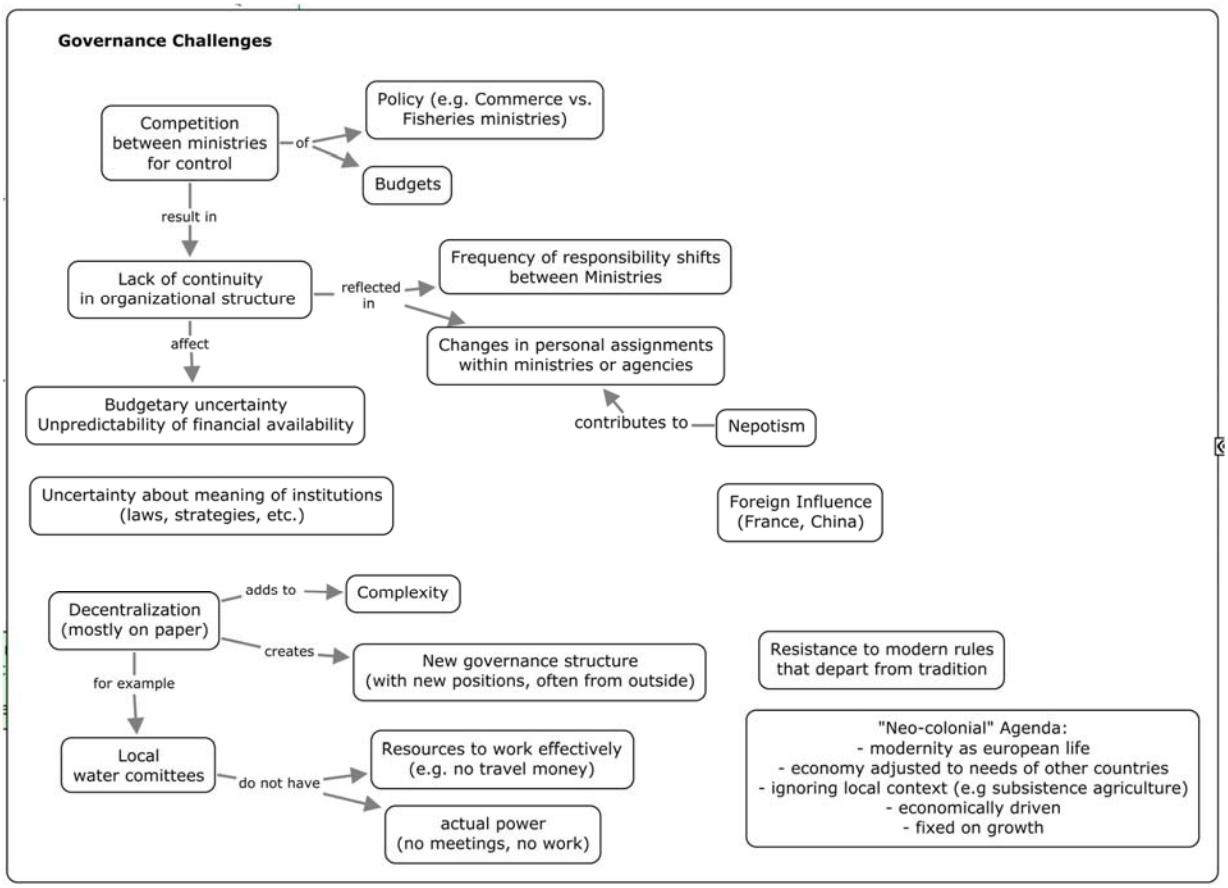
each other. The operation of these loops can undermine sustainability, but that operation potentially can be slowed or halted by several hypothetical interventions, which are depicted as green boxes in Figure 2. Following the examples in Figure 2, *Capacity building programs and knowledge sharing* can improve *Education, knowledge of resource management grounded in the local context*, thereby helping with both *Compliance with laws* and *Enforcement Capacity*. P*articipation of local communities in decision-making and implementation* can increase *Trust*, and *Women's Education* can address the *Diminishing power and availability of roles and strategies for women and poor. Sustainability Visioning* can address and abet all three of these loop processes.

Some of the "variables" or concepts shown in Figure 2 actually are titles that represent a cluster of relationships themselves. These are *Failure of natural resource management, Capacity to implement (enforce) laws,* and *Governance Challenges*. We now describe the concepts and relationships underlying the latter two concepts as depicted when their "box" frames are expanded to reveal the inner structure in Figures 3 and 4.

Several of the current challenges to efficient governance at multiple levels in Burkina Faso have been previously described in Sections 1.2 and 2.2, e.g. Lessons Learned and in Important Remaining Questions in social, economic and political sciences. Some of the concepts and interrelations underlying two of these challenges, e.g. *Institutional Nomadism* and *Decentralization*, are revealed in Figure 3. *Institutional Nomadism* emerges when *Competition between ministries for control* of *Policy* and *Budgets* results in *Lack of continuity in organizational structure,* which is reflected in *Frequency of responsibility shifts between ministries* and in *Changes in personnel assignments within ministries and agencies. T*he latter is profoundly influenced by *Nepotism*. These causal relations affect *Budgetary uncertainty, e.g. unpredictability of financial availability* for those create and/or implement policy as well as *Uncertainty about meaning of institutions (laws, strategies, etc.)* for both government and non-governmental actors in fisheries.

The other governance challenge shown in Figure 3 has to do with *Decentralization* and how to establish governance that functions within and across multiple levels. *Decentralization* is a challenge within itself in that it appears to exist more on paper than in reality. Since heretofore it was ostensibly simpler to manage entirely from the national center in Ouagadougou following the French colonial model, *Decentralization* immediately appears to be a challenging addition to *Complexity* by adding *New Governance structure (new positions, often from outside)* of the social circles in the capital. This is exemplified in the new *Local Water Committees*, e.g. les CLEEs or Committee Local de L'Eau. The complexity becomes apparent in that these committees do not have enough *resources to work effectively* nor do they possess *actual power* to better understand resource challenges and make difficult decisions that are enforced. As such they appear more as a "good idea" poorly conceived or improperly implemented that simply add to frustration and lack of trust in governance so long as these committees stand idle without even enough money to meet regularly.

Figure 3 – Concept Map of Governance Challenges Affecting Fishery Sustainability in BF

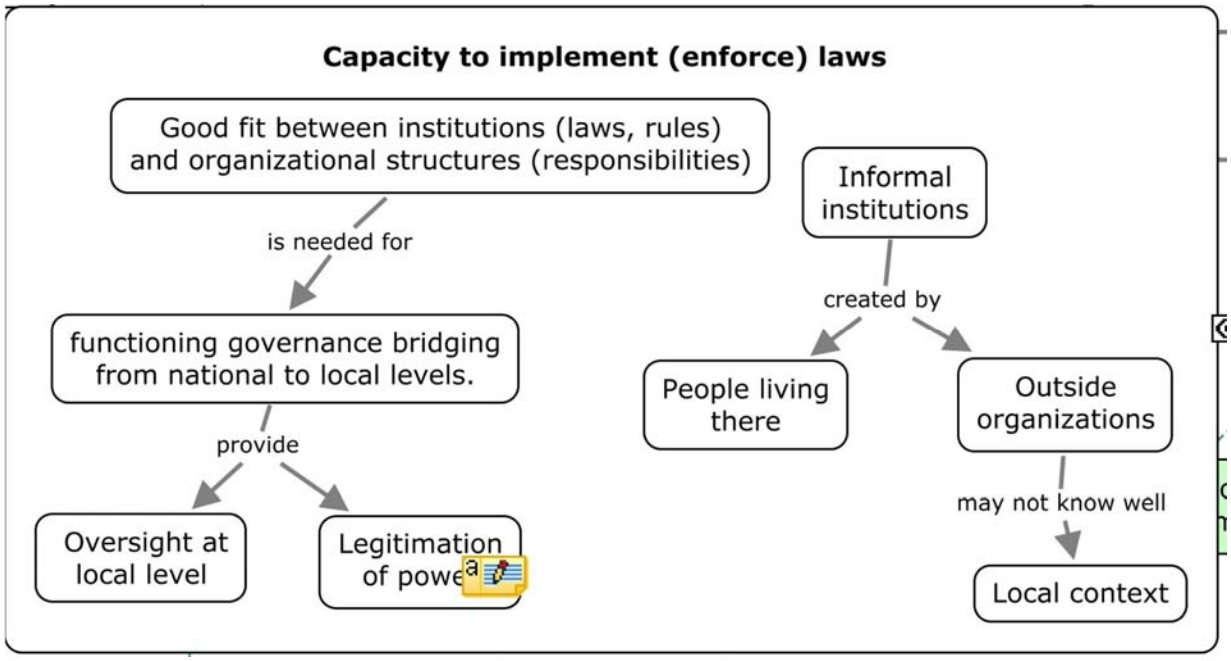


Two other challenges are listed but not structurally elaborated in Figure 3: *Resistance to modern rules that depart from tradition* and *"Neo-colonial" Agenda. T*he former complicates efforts to formulate and implement "modern", e.g. republican, laws at the local level, and could explain the resurgence in reliance in traditional institutions mentioned previously. The latter reflects the tension created by how culture and economy in Burkina Faso appear in part to be profoundly affected by events occurring outside the country. That part of current Burkinabe culture that is embodied in what norms are established and reified as to what is modern and progressive, certainly seems influenced by the international "knowledge" economies that create and run on computers and smart phones. Furthermore, Burkina Faso's economy is profoundly influenced by the activities of world markets as well as government and NGO donors. Just in the area of fish consumption alone, eighty percent 80% of the rising demand for fish is met by international sources. How can governance reach effectively to local levels when so much attention is directed across the national borders to international sources of ideas and economic resources?

Some of the concepts and their interrelations that challenge the creation and sustaining of the *Capacity to implement (enforce) laws* are depicted in Figure 4. The first is the challenge of creating a *Good fit between institutions (laws, rules) and organizational structures (responsibilities)*. To fit laws to their respective responsibilities implies that the language of the law requires actions that can reasonably be expected from the actors, within

government and without, and their respective organizations, that are responsible by the law to perform those actions. A good degree of fit is needed for *functioning governance to bridge from national to local levels*, and this in turn provides both *Oversight at the local level* and the *Legitimation of power* at each level of governance. Such officially legislated multi-level governance can also be complemented by *Informal institutions* in the enforcement of laws. How they complement official institutions and organizational structures is complicated by the fact that *Informal institutions* are created by both *People living there* as well as *Outside organizations*. The latter may not know well the *Local Context*, as is the case with international organizations, both in the private and public sectors. In that case, the formal and informal institutions that they operate by may not fit well with locally sensitive institutions and organizational structures. Such poor fit was clearly in evidence before 1960 when French colonial agricultural policy tried to impose European definitions of modern practice on row crop farming, resulting in widespread deforestation in the Sahel.

Figure 4 – Concept Map of Factors related to the capacity to enforce laws affecting fishery sustainability in Burkina Faso.



3. Discussion

Based on research in the biophysical and social, economic and political sciences, the SUSFISH project has established a foundation of knowledge useful to assess and actualize the potential for sustainable fisheries in Burkina Faso. The SUSFISH project was founded by natural scientists to explore the possibility to analyze and then manage fisheries sustainably based on rigorous biophysical science. However, the long history of technically sound natural science projects that utterly failed in the long run due to social, economic and/or political reasons prompted the most prominent innovation in SUSFISH: research into the non-biophysical factors that might help or hinder the sustainability of fisheries in BF. The research focus was further expanded to look for interactions both within and *between* biophysical and non-biophysical factors using scenarios and systems analysis. SUSFISH research set out to establish a factual basis for sustainable fisheries. But based on the recognition that such an effort to look thoroughly *across* disciplines can never be comprehensive in only a few years, SUSFISH project research was oriented to conclude by identifying the most important on-going questions for future research. In this section, we summarize the most prominent findings (Lessons Learned) and questions generated by SUSFISH research and conclude with some of the salient implications of such research as indicated from scenarios and systems analysis.

3.1 Review of major findings

The SUSFISH project has clearly met its overall goal of providing the science basis for making fisheries sustainable in Burkina Faso. This has been achieved both in terms of knowledge generated as well as capacity building to apply that knowledge. Capacity building has been achieved through provision of tools (software for analysis and hardware for fish monitoring) as well as training in the use of those tools. This includes the use of different kinds of gear to sample both fish (gill nets, electrofishing, etc) and benthic invertebrates and the protocols for handling and the analyzing the samples, especially taxonomic classification. It also includes the use of statistical software and modeling to analyze and identify significant trends in the data sampled in the field.

Knowledge has been generated both in terms of concepts and facts about Burkina Faso aquatic ecology and society. This new information can serve as a foundational database that can inform the formulation and implementation of policy, providing benchmark data from which to measure progress and set targets performance levels for policy and practice. For example, not only has SUSFISH research generated the most current and comprehensive species lists for BF, it has identified the significance of the relative scarcity of some of its species: a significant fraction (56%) of fish species in Burkina are threatened. SUSFISH has established the data basis to identify the multiple sources of those threats and quantify their impacts on aquatic species. Broadly, in Burkina Faso the presence, diversity, trophic level, density and biomass of certain fish and benthic invertebrate genera and species respond negatively to a range of anthropogenic pressures. Such

BI as well as fish taxa respond not only to threats and pressures but also to landscape and habitat parameters. As such certain genera and species can be useful as bio-indicators of

water body typology, and river morphology and structure in Burkina Faso catchments as well as Land Use-Land Cover (Habitat Type) parameters.

It was also established that data on BI (abundance, species richness) also reflect water quality parameters such as conductivity, oxygen demand, ambient temperature of the water column, and productivity of a water body), so aquatic species can be used as bio-monitors of water quality both for managing fisheries as well as the security of water supplies for society.

The practical implications of SUSFISH research is that it provides specific knowledge about the sensitivity of certain fish and benthic invertebrate taxa to specific pressures and/or clusters of pressures that offer the data basis for monitoring the presence and impacts of pressures. Overall, SUSFISH surveys demonstrate that such parameters as fish size, abundance and diversity are related to the quality of fisheries and habitat management. Therefore, both fisheries and water can be better managed based on science that rigorous monitors and manages multiple levels: aquatic taxa, the water column, habitat quality and surrounding land uses, and the human activities that generate pressures impacting these aquatic and terrestrial habitats. SUSFISH data indicate that fish management must be informed by data at scales larger than landscape, since fish biodiversity is related to their mobility and, ultimately, to water network connectivity.

Over the long-term, this project has established that monitoring systems that were developed based on data from catchments outside BF are of limited use for monitoring and managing BF catchments. There is a clear mandate to develop a new monitoring system based entirely on data from BF. SUSFISH also has provided an outline of different pathways to develop such a BF-specific monitoring system, e.g. a three tier system with increasing accuracy and precision can be established: level 1: a rapid field methodology; level 2: a Biotic Score; and level 3: a Multimetric Approach.

As previously noted, SUSFISH was founded in recognition of the history of failure of development projects grounded only on technical and/or scientific advances. In Burkina Faso alone SUSFISH research found examples of abandoned equipment and infrastructure (fish ponds, refrigerators, fish-weighing scales, fish shops) to support the modernization of fisheries that testify to this. For that reason, SUSFISH sponsored research into the social, economic and political barriers and bridges to sustainable fisheries. Our research indicates that while some encouraging examples exist, there are abundant barriers to sustainable fisheries provided by challenges of governance at multiple levels in Burkina Faso.

A prominent overarching challenge is that it appears that fisheries management is not equally applied all over Burkina Faso but is concentrated in a few large reservoirs of "national economic interest", e.g. *Ziga, Bagre, Kompienga,*and *Sourou*. Outside of these major reservoirs dominated by commercial fishermen who are regulated and in good communication with government officers, communication is not so good for management organs devoted to smaller reservoirs, except for four fishing concessions given to the associations of the local fishermen (*Bapla, Moussodougou, Tandjari, Lera*). Aside from these few examples of successful organization of local management capacity, for the most part there are gaps between National and lower levels of governance. Briefly, a governance

system that effectively functions from the central, national level out to the regional and local levels has yet to be established. Often the link between law and practices to monitor fisheries is missing (law is not adopted to practice). Therefore there is little effective police monitoring or enforcement of fishing practices at the lower levels, e.g. smaller-scale fisheries.

While efforts to decentralize management authority have been underway for years, the failure to comprehensively bridge institutions from national to local levels is hampered by the frequency of shifts of governance responsibilities (institutional nomadism) for fisheries management at the national level (Administrative Flux). One salient example of such poor communication is the general lack of expertise that is regionally or locally available for consultation. As a result, progress in improving fishing methods is blocked by lack of capacity to learn or to organize.

In the face of such poor inter-level communication and sporadic or absent monitoring the use of illegal equipment and fishing practices only mounts. It is hard to imagine how trust in governance can be built to strengthen compliance with laws and policies under such conditions, and evidence of this eroding trust is that in some areas local fishermen have swung their allegiance from republican to traditional authorities. Traditional authorities still constitute legitimate local sources of governance. Traditional institutions play a vital role in reaffirming the identity of communities reliant on aquatic ecosystems and thereby broadly influence water and fish management. However, the current governance structure has failed to link and harmonize republican and traditional sources. And efforts to decentralize have been poorly implemented, e.g. local management committees lack the funding to even meet regularly, or have been taken over by special economic or political interests, e.g. *elite capture*.

The governmental bodies responsible for the fisheries sector were unaware of women's specific role in the fisheries management. Consequently they did not consider them enough as crucial actors in their strategic and political programmes. SUSFISH's sociological research on fish as important income generating resource shed light on women as important preserving stakeholders (e.g. *systemerhaltende Funktion*) in the economic, nutrition and health domains. Interdiscplinary work revealed important cross-sectoral activities, interrelated power relations and hindering factors that play key roles in the value chain issue of the resource fish in Burkina Faso. However, notwithstanding their important economic role, since women are excluded from decision-making processes on local levels, the focus of future analysis should be oriented towards the impeding factors emerging from incomplete or misguided education, structures of associations and power asymmetries. These findings resulted in the draft of a strategy for the integration of these aspects in the fisheries management policies, which was developed in SUSFISH.

One pillar or core element of SUSFISH research was to establish or intensify cooperation among partners within the project (nationally in Burkina Faso and in Austria as well as internationally between institutions of both involved countries). Some of them needed capacity-building measures to foster cooperation across disciplinary and institutional boundaries. Therefore SUSFISH developed a set of cooperation-promoting activities, such as joint interdisciplinary fieldtrips, cross-disciplinary workshops, joint lectures, shared

supervising models for students (cross institutionally), system analysis and concept modelling. A second pillar of SUSFISH applied research was networking with new partners nationally as well as internationally. For instance a regional network of research institutions on fisheries and aquatic ecology could be initiated through the intensification of exchange and dissemination activities between Benin, Côte d'Ivoire and Burkina Faso. Both pillars contributed significantly to the promotion of institutional capacities of socio-political ecology in the higher education system of Burkina Faso. With the conclusion of SUSFISH it is obvious that further efforts will be crucial for a sustainable continuation of the changes made in this sector.

3.2 Review of the Implications of SUSFISH research

SUSFISH partners used three means to examine the implications of the project's findings: elucidating prominent remaining questions, developing scenarios that elaborate different development paths of aquatic biotopes in the future, and systems analysis of hypothetical relationships between factors that influence important trends and scenarios identified by SUSFISH research. We summarize key findings in all three areas below.

Many of the questions outstanding in the biophysical sciences emerge from concerns about how to extend SUSFISH to better sample and classify aquatic taxa as part of assessing the impacts of more than one threat at a time. For example, how to assess the effects of complex clusters of factors on aquatic taxa, e.g. Those involved in river network connectivity, or dam size and river dynamics. The answers to such questions could then be used to develop the protocols to establish bio-monitoring systems based solely on BF aquatic taxa, e.g. fish and benthic invertebrates. However, our findings of how severely reduced in size and abundance local fish are in local markets suggest that local aquatic biotopes and their resident fish communities are so severely impacted that they cannot be rapidly or completely restored under the current governance regime. Therefore, questions arise as to what artificial methods can boost fishery productivity; what are their advantages and disadvantages, and how can we improve and apply them in Burkina Faso?

Questions outstanding in the social, economic and political sciences are partly centered on how to improve future research methodologically, e.g. how communication is influenced by language or is the concept of sustainability concept too vague to be useful in co-creating knowledge with local stakeholders in the future? However, most of the questions focus on how to extend and test our preliminary findings to better describe and quantify various governance challenges and how they impact fisheries. For example, how severely do the unpredictable shifts in national responsibilities to formulate and administer policy impact the communication about and implementation of policies to manage fisheries, aquatic biotopes and surrounding habitats? How can we assess and describe different forms of corruption, efforts to improve links between national and local governance levels, and efforts to harmonize republican and traditional governance institutions? Finally, at more local levels, what methods are needed to assess how local knowledge influences the formulation and implementation of fishing regulations and what types of participatory processes might enhance policy and practice in fisheries management?

SUSFISH applied participatory research methods to develop scenarios as ways for experts and partners to examine the dynamic implications of the facts and questions generated by the project. How might events unfold under different sets of conditions? For example what are the medium to longer-term consequences of accumulations of pesticides, sediment, agricultural fertilizers, or invasive species on the quantity and quality of littoral or aquatic habitat, water column or the resident aquatic taxa? What are the consequences if aquatic communities become "trapped" in a new regime where toxic phytoplankton are dominant or where fish adult body size is irreversibly reduced, capping any effort to increase fishery productivity? Such exercises did not test or verify any particular system trajectory, but they allowed participants to reconsider their assumptions and questions in light of the dynamics that they anticipated, and it further allowed elaboration of what particular variables and parameters ought to be measured to better understand how the system is changing. As such, these exercises can inform future research agendas.

Finally, the SUSFISH project used conceptual mapping exercises to examine the possible structures of relations that might underlie the dynamics hypothesized in several scenarios. These exercises extended analysis of the system from a hierarchical set of relationships posited under the scenarios, to more complex patterns of relationships: webs and feedback loops. The efforts to map these concepts and their relations did not verify any particular set of concepts or pattern of relations, but they identify how some partners imagine they are related and propose to analyze them in the future. Mapping of biophysical factors related to several fishery scenarios showed they do not "stand alone" but are linked in a web of relationships that affect *Fish Productivity* and *Fish Yield*. Mapping of non-biophysical factors associated with several scenarios revealed the central role trust plays in a nested set of related feedback loops that influence *Governance Challenges*, our *Capacity to enforce laws* and *Failure at natural resource management*. This suggest the possibility that *Failure of natural resource management*, which consists of water pollution, overfishing, water overconsumption, and erosion leading to sedimentation, can be analyzed not as one or several single chains of causes but as a set of loops that reinforce and augment each other.

4. Conclusions

The SUSFISH project has clearly met its overall goal of providing the science basis for making fisheries sustainable in Burkina Faso. This has been achieved both in terms of knowledge generated as well as capacity building to apply that knowledge. Capacity building has been achieved through provision of tools (software for analysis and hardware for fish monitoring) as well as training in the use of those tools. Further achievements were made by integrating these new training elements in the curriculum development for applied ecology. Knowledge has been generated both in terms of concepts and facts about Burkina Faso aquatic ecology and society. This new information can serve as a foundational database that can inform the formulation and implementation of policy, providing benchmark data from which to measure progress and set targets performance levels for policy and practice. The practical implications of SUSFISH research is that it provides specific knowledge about the sensitivity of certain fish and benthic invertebrate taxa to specific pressures and/or clusters of pressures that offer the data basis for monitoring the presence and impacts of pressures. However, despite anthropogenic pressures fish presence and diversity remains higher if hydrological connectivity of the regional surface water network is maintained, allowing fish migration to replenish local population declines.

Overall, SUSFISH surveys demonstrate that such parameters as fish size, abundance and diversity are related to the quality of fisheries and habitat management. Therefore, both fisheries and water can be better managed based on science that rigorously monitors and manages multiple levels: aquatic taxa, the water column, habitat quality and surrounding land uses, and the human activities that generate pressures impacting these aquatic and terrestrial habitats. SUSFISH also produced reliable information that will be used to improve the governance of water and fish. For example, the list of fish species is a legal and technical requirement that was never fulfilled: SUSFISH proposed a list of species. The development of the Red list of fish for BF will give insight for diversity conservation, not only for fish but also for other taxa such as benthic macro-invertebrates. Overall, a significant fraction (56%) of fish species in Burkina is threatened.

A major challenge is that governance is not uniformly enforced in BF. Because of multiple kinds of legal and administrative statuses for fisheries according to reservoir type (large or small scale), there are gaps between National and lower levels of governance. This gap may lessen if consideration of local communities' opinion in fisheries will be improved in the process of decentralisation that started 1.5 decades ago. However, more must be done to integrate the formulation and enforcement of policy. Creation and enforcement of fisheries policy is hampered by the frequency of shifts of governance responsibilities (institutional nomadism) for fisheries management at the national level (Administrative Flux). Linkages between law and practices to monitor fisheries are missing at various levels such that law is not adopted in practice. Therefore effective police monitoring or enforcement of fishing practices is scarce at the lower levels, e.g. smaller-scale fisheries. SUSFISH provided a comprehensive report on governance in the fisheries sector, which was shared with practitioners in order to link scientific results with administrative experience.

In terms of integrating better awareness of social trends in fisheries research and policy, at the political level in Burkina Faso the concept of gender is adopted more due to outside

pressure, e.g. from development policy, than from internal evolution. This approach risks to remain theoretical and development driven, as it is distant from peoples' livelihoods and leads often to misunderstandings. SUSFISH research contributed significantly to shed light on the role and status of women in the complex social and political structure of fisheries management in Burkina Faso. These findings could be integrated in policy formulation at ministerial level and thus foster a more applied approach towards gender equality.

In terms of education and research, SUSFISH developed a strong partnership at national as well as on international level. The strength is based on (1) interdisciplinary collaboration and exchange, (2) development of innovative research methods (3) development of new curricula elements to promote research in practice (4) team work (5) joint dissemination activities. Significant effort was made to diminish existing asymmetries among higher education systems in global North-South-relations, but was hindered by structural deficits. For instance instruments such as scholarships for students from developing countries are very useful. But the potential for the promotion of young scientists is restricted by the following factors: (1) good research is diminished when selection criteria are applied based on development priorities rather than academic priorities. (2) To succeed as researchers to support national policy formulation and in an international market for science, graduate students from Burkina Faso need additional skills in scientific practice to define research questions and independently carry out research projects. (3) To that end, much more time is needed to fully develop the potential of supervisor-student relations as part of teamwork maturing, and changes need to be made in Burkinabe curricula at the levels of secondary school and university. SUSFISH cooperation enabled some significant initial experiences in this direction. But structural changes in the education system are needed more generally: applied science training should be given increasing priority to foster integration of theory and practice and prepare students with potential to do scientific research at the graduate level.

In terms of future cooperation based on improved networks of applied scientists, the memorandum of understanding signed between Ouagadougou University and BOKU-University is an important asset. Moreover the equipment purchased by SUSFISH will still be used by the Burkinabe institutions. Student exchanges and joint supervision of students among the involved higher education institutions will foster future cooperation and research networks. SUSFISH results of the interdisciplinary studies on food security and nutrition were used to develop training manuals on the use of fish in diet for practitioners. All these advances in concepts, data, skills acquisition and equipment can serve as a solid foundation for the re-establishing sustainable governance of fisheries and aquatic ecosystems as a post-revolutionary government takes shape in the coming years.

5. Appendix: Scenarios of Future Developments of Burkina Faso fisheries

Contents

Scenario 1

SEDIMENTATION

1. Process or Trend influencing Fishery Sustainability: Sustained or increasing erosion rates leads to sedimentarion filling reservoir basins.

2. Key Words: Erosion, Wind, Agriculture, tree loss

3. Scenario showing how sustainability is influenced (3 sentences or less):

   Sedimentation fills reservoir basins reducing available water volume, thereby reducing the area and the duration of flooding of fish nursery habitats and raising ambient water column temperatures.

4. Important factors involved in this scenario:

Soil erosion and overland transport rates
- Surface runoff volume and velocity,
- Wind Average Velocity and Duration
  - Aridity
  - Desertification
  - Tree density
    - Deforestation rates,
      - Agricultural cultivation technologies and application intensities
    - Tree planting rates
  - Effectiveness of Surface soil transport barriers
    - Stone bund building and maintenance rates
  - Monsoon length and intensity
  - Livestock impact on soil structure
    - Livestock grazing rates and duration

Soil Dynamics in Reservoir benthos
- Rate of soil throughput through reservoir
  - Rate of soil inflow, Rate of soil outflow
  - Rate of soil removal

5. Relations between factors that influence this scenario:		
Factors involved:	How they interact:	Results
Deforestation rates, wind speed, soil erosion rates	Reinforcing feedback loop	Erosion rates sustained or increase as tree cover declines

6. Key Questions or Uncertainties:

- This hypothesis is controversial and only partly supported by field measurements in Burkina Faso (citation).

Scenario 2:

Fish productivity declines as average habitat affected

1. Key Words:

2. Scenario showing how sustainability is influenced (3 sentences or less):

Fishery management becomes sustainable as fish managers can lower habitat degradation which are useful for fish reproduction and fish feeding.

3. Important factors involved in this scenario:

Physical habitat alteration
- Sand and gravel mining
  - -Modification of spawning
  - -Destruction of fish eggs and larvae
- Deforestation of aquatic plant
  - Destruction of plants by Flood, grazing
    - -Destruction nursery
    - -Destruction of fish hiding place
    - -Reduction of food
- Riverbank development
  - Modification for agriculture and vegetable farming
    - -Modification and reduction of floodplain
    - -Reduction of available food
  - Roads development and bank protection
    - -Reduction of floodplain
- Sedimentation
  - From wind and rain
    - -Reduction of water volume
    - -Destruction and reduction of both available spawning and nursery place
- Perturbation due to livestock walking during pasture and drinking period

Chemical alteration
- Eutrophication by living wastewater, sewage
- industrial and urban wastewater
- Toxic chemicals
  - heavy metals from gold mining

pesticides, organic compound

5. Relations between factors that influence this scenario:		
Factors involved:	How they interact:	Results
-Modification of rivers substrate and their vegetation -Fish population	Any change on river feature has an impact on fish population	Probability of loss of the ecosystem quality and biodiversity

Scenario 3

1. Process or Trend influencing Fishery Sustainability: Macrophyte Proliferations

2. Key Words: Fertilizers, Agricultural Practices, Aquatic Macrophytes

3. Scenario showing how sustainability is influenced (3 sentences or less):

Excessive inputs of artificial fertilizers may stimulate the proliferation of aquatic macrophytes (e.g. *Ceratophyllum submersum* in the Boura reservoir), then reducing the catchability of fish (among other problems).

4. Important factors involved in this scenario:

Agricultural intensification (increased fluxes of inorganic nutrients coming from watershed and/or upstream inland valleys), still amplified in case of weak renewal of water masses during the flooding period (with a limited dilution of nutrient stocks *in situ*).

5. Relations between factors that influence this scenario:		
Factors involved:	How they interact:	Results
Macrophyte growth, fertilizers uses, transfers from watershed and/or upstream inland valleys.	Stimulation	Increase in fertilizers uses may stimulate macrophyte growth.

6. Key Questions or Uncertainties:

"Alternative Stable States Hypothesis": potential shifts from macrophyte dominance towards phytoplankton dominance (and inverse). Two resilient states (for aquatic ecosystems) but with very different (associated) ecosystem services.

Scenario 4

Agro-chemical contamination of lake sediments, water column and tissues of fauna living in and around the lake.

1. Key Words: Cocktail of pesticides, Agricultural Practices, Watershed state (land use)

2. Scenario showing how sustainability is influenced (3 sentences or less):

Because of agricultural intensification pesticide use has become *banal*, leaving cocktails of chemical residues. Their impacts on the aquatic ecosystem productivity (disrupting the food web, trophic cascades,) and the reproductive efficiency and growth of (commercial) fishes remain unknown. Their potential accumulation within fish tissues has to be explored both for fish populations as well as consumers health are in concern.

3. Important factors involved in this scenario:

Agricultural Intensification
- Crop Production and Water Use
  - Production rates for commercial farming (cotton, tomatoes, vegetables)
    - Regional demand for vegetables, esp. tomatoes
    - International and regional demand for cotton
  - Production rates for subsistence farming

Pesticide Use
- Best-management-practices in application
  - Time frame of application, Quantity, Quality

Water Use
- Population density, Average distance farm to market, Crop production rates

Land Use
- Population density, growth rate, migration rates
- Land use intensification of watersheds
  - Urbanization, Road network development, Mining development, Reservoir development
- Land rights
- Ratio of fallow to cultivated lands in the watershed
- Climate Change (Increased variability of rainfall, wind, temperature)

Pesticide Dynamics

Movement from farm to the hydrosphere
- Surface water Runoff Rate, Percolation rate to Groundwater, Atmospheric dispersal rate (irrigated water aerosols) to lake water
- Recycling rate of aquatic water to the farm (irrigation)
  - Linear distance from farm to lake
- Chemical transmutation of pesticides between farm and lake
  - Biological and Geochemical interactions

Movement through the aquatic ecosystem (bio-accumulation)
- Pesticide concentrations in Water Column, Sediments,

Tissues of Fauna and Flora
Pesticide transfer rates between different levels of the food chain
Bio-amplification
Movement out of the aquatic ecosystem
Fish catch rate, Fish consumption rate, Transfer rate from fish to human tissues (bone, fat, muscle)
Pesticide movement out of lake
Flushing rate out of reservoir during rainy season
Water withdrawal rate for human and animal use
Irrigation
Cotton production rate, Cotton-related water demand
Domestic use,
washing, cooking,
Animals – domestic (livestock) and wild
industrial use, mining, road and building construction
Evaporation rate
Consider increasing importance of non-linear responses as climatic variability increases, e.g. a few extreme events can dominate the yearly dynamics.

Assessing the State of the System (establishing a baseline for monitoring, modeling)
Aquatic ecosystem productivity
disrupting the food web, trophic cascades
Reproductive efficiency and growth of (commercial) fishes
Human health related to water contamination

5. Relations between factors that influence this scenario:		
Factors involved:	How they interact:	Results
Pesticides uses; nature and origins (harmfulness) of chemicals; deregulation of farming practices; transfer to water masses (influence of land use and hydrology as well); transfers to fish communities; impacts on reproductive pathways; flesh	To be studied	Pesticides do clearly threaten aquatic ecosystems with un known impacts on fish populations and further, on their consumers (humans as animals).

6. Key Questions or Uncertainties: Huge and complex scientific task….

Chemical Impacts (Pesticides, Herbicides, Fungicides)

Aquatic ecosystem (fish) productivity
Structure of Communities

Scenario 5

Cyanobacteria proliferations

1. Key Words: Cyanobacteria, water quality, anthropogenic pressures, watershed, buffer areas

2. Scenario showing how sustainability is influenced (3 sentences or less):

In the Nakambé basin, cyanobacterial assemblages are hugely dominant in the surface waters of most reservoirs. Their dominance seems associated to increased anthropogenic pressures exerted on watershed (population densities) and immediate buffer areas (land use). Cyanobacteria may constitute trophic dead-end (unpalatable for most species). Many of them exhibit harmful toxicity with potential accumulation along the food-web, including fish and their consumers

3. Important factors involved in this scenario:
Anthropogenic pressures on watershed and immediate vicinity of reservoirs. Cyanobacteria facilitation. Pelagic food-webs..

5. Relations between factors that influence this scenario:		
Factors involved:	How they interact:	Results
Anthropogenic pressures; solid and dissolved fluxes towards aquatic ecosystems; cyanobacteria fitness	Complex loop involving fluxes (from the watershed) and stocks (with aquatic ecosystems, including stoechiometry).	Anthropogenic pressures may facilitate cyanobacteria proliferations.

Scenario 6

Available water volumes within reservoirs at the end of the dry season decline below thresholds critical to fish capacity to survive and reproduce in the wet season.

1. Key Words: Water reserves; multiple uses context; hydrological uncertainty

2. Scenario showing how sustainability is influenced (3 sentences or less):

Excessive withdrawal of water during the dry season may considerably reduce the amount of water available within reservoirs at the end of the dry season (for agriculture, mining or

other purposes). At that time, future fish generations are under the dependency of the quantity (and quality, see PC-BP2) of potential genitors whose number is partly controlled by the available water volume. This may select species and globally impoverish fish diversity. Dry spell may also be involved in case of 'poor' rainy seasons (reduced inflows).

3. Important factors involved in this scenario:

Water volumes at the end of the dry season
Water volume at end of wet season
Rainfall patterns (duration, intensity) during wet season

Water withdrawal rates
Surface Water demand for (in order of priority):
Mining, industry, Irrigation, livestock, domestic use
Irrigation
Demand for agricultural produce from France, Food Price differential France / Burkina Faso, Export rate of BF produce
Groundwater demand
Evaporation
Climatic Variability (rainfall patterns unpredictable)

Fish survival rate during the dry season
Availability of food
Competition from other aquatic species
Productivity of the ecosystem
Fish removal rate
Fishing Pressure
Predation pressure
Fish Reproductive Capacity
Number of large adult fish (stocks of future genitors)
Re-stocking success rate
Fishing pressure
Re-colonization rate from the hydrological network
Connectivity
Types of fishing practice
Fishing gear (nets, traps) across river
Number of barrages in the network
Number of Fish ladders (*Passes migratoires*)

Availability of Food
Availability and Quality of Habitats
Competition pressure to use habitat
Diversity of potential habitats for future fish genitors
Littoral macrophyte density and diversity (grasses, shrubs, etc)
Water quality (Oxygen, Chemicals, Temperature)
Substrate diversity (rocks, mud, detritus,)

5. Relations between factors that influence this scenario:		
Factors involved:	How they interact:	Results
Available water volumes; fish genitors;	Impacts on habitats (number and diversity) and then on fish assemblages (abundances / diversity).	Insufficient water reserves at the end of the dry season may alleviate the reproductive success of fish populations (lost of genitors).

6. Key Questions or Uncertainties:

Could be controlled by restocking of selected species?

Scenario 7

1. Process or Trend influencing Fishery Sustainability:
   Artificialisation of hydrographic networks

2. Key Words: Connectivity; fish migration; natural restocking of reservoirs

3. Scenario showing how sustainability is influenced (3 sentences or less):
Fish stocks are under the dependency of permanent water resources where most genitors are (naturally) living. Upstream migration during the flooding period is the first natural restocking pathway. Cascades of infrastructures along the same hydrographic network – and the absence of by-pass for fish – disrupt the hydrographic connectivity during the flooding period and do not allow fish to migrate upstream and then (re)colonize lakes and reservoirs.
   Raymond Ouedraogo adds: lost capacity to migrate negatively impacts fish growth and reproduction

4. Important factors involved in this scenario:
   Cascades of infrastructures; fish migration; natural restocking

Scenario 8

1. Process or Trend influencing Fishery Sustainability:
   a. Destruction of infrastructures

2. Key Words: Infrastructures' preservation and maintenance

3. Scenario showing how sustainability is influenced (3 sentences or less):
   a. Destruction of infrastructures will de facto destroy fisheries previously associated to the water masses… created by the infrastructures…

4. Important factors involved in this scenario:
a. Infrastructures protection and maintenance. Crocodiles' chambers. Hydrological disturbances (excessive flash flood). Dimension of current (and future) infrastructures (dikes, spillways,…

5. Relations between factors that influence this scenario:		
Factors involved:	How they interact:	Results
Infrastructure's states. Maintenance. Crocodiles. Hydrological disturbances..	Crocodiles do create excavations within dikes Poor maintenance stimulate degradation.	Hydrological disturbances may destroy poorly preserved infrastructures, and then associated activities (fisheries among many other services).

Scenario 9

1. Process or Trend influencing Fishery Sustainability:

Rising importance of International Fish Markets and Fish-Products Importations to BF

2. Key Words: Infrastructures' preservation and maintenance

3. Scenario showing how sustainability is influenced (3 sentences or less):
The low prices of imported fish products do not allow the exploitation of local fish populations to become a sustainable activity. Lack of profitability because of market competition with imported fish-products (to be developed).

Scenario 10

1. Process or Trend influencing Fishery Sustainability:
   Fishermen or agro-fishermen?

2. Key Words: Polyactivity; patrimonialisation (patrimonialising?) of fisheries activities, heritability

3. Scenario showing how sustainability is influenced (3 sentences or less):
   Except on (very) large reservoirs; fishermen are not professionals. These stakeholders are firstly farmers who diversify their activities – and income's sources – in fishing (all year round or seasonally). Fisheries activity is not patrimonial (as farming could be) and there is no real heritability of this skill….(to be developed).

4. Important factors involved in this scenario:
   Household's strategies; diversification; professionalization; polyactivity

Scenario 11

1. Process or Trend influencing Fishery Sustainability:
   a. 'Political commitment'

2. Key Words: Fisheries-sector development; large vs small reservoirs; centralization and decentralization; new actors (Rural communes); to be developed

3. Scenario showing how sustainability is influenced (3 sentences or less):
   a. The large number of (very) small infrastructures is an opportunity. Small but numerous and scattered, fish-products extracted from small reservoirs may immediately impact the riverine consumers. These fish-products may have a huge impact on an important rural (often vulnerable) population. Economic weight globally unknown. To be developed….

4. Key Questions or Uncertainties:

   The real impact of very small scale fisheries on their immediate consumers remains to be thoroughly assessed (by field works and not only by the triturating of secondary data… *to be developed*.
   How and why to develop efficiently the exploitation of (very) small reservoirs? Is there a political commitment for this kind of infrastructures? Is there a redundancy between their local importance (but small and scattered, poorly documented) and the political recognizing of this importance? So what? (*to be developed*).

Scenario 12

1. Process or Trend influencing Fishery Sustainability:
   a. Increasing populations of alien fish species cause indigenous species to decline

2. Scenario showing how sustainability is influenced (3 sentences or less):

a. Sustained invasion and subsequent reproductive success of alien fish species causes their resident populations to grow. As the alien fish species outcompete indigenous species for food resources, the latter populations decline.