DAFNE

A **D**ecision-**A**nalytic **F**ramework to explore the
water-energy-food **NE**xus in complex and transboundary
water resources systems of fast growing developing countries

MODELS OF DEMOGRAPHIC, CULTURAL AND SOCIAL DEVELOPMENTS IN THE OMO-TURKANA AND ZAMBEZI RIVER BASINS

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Abbreviations

CLD: Causal loop diagram

DoA: Description of Action (Annex I of the Grant Agreement)

NGO: non-governmental organisation

NSL: Negotiation Simulation Lab

SDC: social, demographic, and cultural

W-E-F: Water-Energy-Food

WP: Workpackage

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1. INTRODUCTION

The DAFNE project is a research initiative among several African and European research organisations funded by the EU Horizon 2020 program. By means of participatory research, the objective is to develop a framework for analysing decisions for resource management that takes into account the links between the water, energy and food sectors. The project is carried out in two case studies in the Omo-Turkana basins and the Zambezi River basin. The study therefore involves collecting knowledge from stakeholders with differing backgrounds and expertise related to water, energy and/or food. The results, including the analytical framework, will be made available to stakeholders when the project ends in August 2020.

The ultimate goal of the DAFNE project is development and dissemination of a decision-analytic framework for Participatory and Integrated Planning in 2020. This framework will allow local users to investigate the social, economic, and ecological impacts of infrastructural developments in the river basins, and to assess alternative pathways for avoiding or reducing these impacts.

DAFNE's Description of Actions (DoA) defines Deliverable 4.3 as a "[d]escription of models that link demographic, social, and cultural developments with a selection and implementation of economic and water management policies with reference to the Omo and Zambezi case studies (DoA, p. 26)". The social models described in this deliverable allow identifying links among diverse societal and resource-related factors in both case studies. Such links should proactively be addressed in Participatory and Integrated Planning to deal with current challenges and reduce negative consequences of future developments in the Omo-Turkana and Zambezi basins.

1.1 BACKGROUND: PURPOSE AND CONTEXT FOR SOCIAL MODELS IN THE DAFNE PROJECT

As part of the DAFNE project, researchers have been studying the role of socio-economic and cultural issues that are linked with the water, energy and food sectors, also referred to as Water-Energy-Food nexus (W-E-F nexus), in the Omo-Turkana and Zambezi basins.

Osnabrück University (UO) is leading Task 4.4 on modelling social, demographic and cultural developments (for example human health, employment, resettlement and urbanization) that are related to the W-E-F nexus within the two basins. Other DAFNE partners for Task 4.4 are University of Zambia (UNZA), Eduardo Mondlane University (UEM), African Collaborative Centre for Earth Systems Science (ACCESS) and Water and Land Resources Centre (WLRC) of Addis Ababa University, who supported Osnabrück University with their regional expertise and established contact with local stakeholders. Moreover, ICRE8 as leader of work package (WP) 4 aimed to ensure that the social models fit within the set of models to be developed within the scope of this WP.

In agreement with partners in WP 4 and in compliance with the Task 4.4 description, the decision was made to develop the social models as system dynamic models. This type of model facilitates a relatively robust identification of links and feedbacks within complex social-ecological systems, which are composed of numerous interacting components. System dynamic models allow the user to explore how certain trends (e.g., population growth) bring about other direct or indirect developments (e.g. resource-related impacts). These effects may be intended or unintended. In this way, system dynamic models can show how socio-economic phenomena and environmental aspects interact, which represents important information for resource-related decisions in the W-E-F nexus. As indicated in the task description, demographic development as well as related drivers and responses were given special consideration in the social models. System dynamic models do not require quantitative data as input. Instead, qualitative data about links in the system of interest are often elicited in cooperation with stakeholders: in a first step, individual system representations are created with single stakeholders. These individual models are subsequently merged. The resulting model combines knowledge from various stakeholders and can be used as a tool for social learning, in which the stakeholders expand their knowledge about the system of interest and learn about the perspectives of other stakeholders.

For both DAFNE case studies, a separate social model was developed based on a participatory approach, in which stakeholders shared their expertise with DAFNE researchers. In the case of the Zambezi model, the participatory research process was linked to a Negotiation Simulation Lab (NSL) workshop hosted by the DAFNE project.

The final models may be used to identify critical issues in the respective social-ecological system, links between socio-economic and resource-related factors and the influence they have on each other. The models help to identify knowledge gaps requiring further research and support our understanding of where potential competing activities, feedbacks and side effects may be, thus supporting long-term decision-making in the Zambezi and Omo-Turkana basins. The social models will be made available to the stakeholders involved in model development and to DAFNE researchers to support the creation of the decision-analytic framework.

1.2 Relationship between Deliverable 4.3 and the underlying theses

This deliverable describes the social models for the Zambezi and Omo-Turkana basins, which were developed by Nils Eikemeier (Eikemeier, 2018) and Jan Sodoge (Sodoge, in preparation) within the scope of their theses. Both students were supervised by Johannes Halbe and Geeske Scholz.

Nils Eikemeier, a student of the master's programme 'Environmental Systems and Resources Management' at Osnabrück University conducted stakeholder interviews and developed the social model of the Zambezi basin within the scope of his master's thesis. This report represents a summary of the method and results from his thesis, which has been attached as in appendix I.

Jan Sodoge, a student of the bachelor programme, 'Applied Systems Science' at Osnabrück University carried out similar research for the Omo-Turkana basins. At the time when this report was published, his bachelor thesis was still in preparation. Some of the results of his thesis have been attached in appendix 2.

1.3 Integration with other DAFNE tasks

The social models for the Zambezi and Omo-Turkana can be linked with several other tasks of the DAFNE project to study W-E-F nexus issues. Both models do not require quantitative datasets from WPs 2 and 3 as inputs because they were implemented as system dynamics models in compliance with the Task 4.4 description (see chapter 1.1). However, quantitative data from these WPs can be easily converted to serve as qualitative input (e.g. "increase of population" as qualitative information derived from a quantitative demographic dataset). This allows the exploration of the consequences of projected developments as compared to the current situation. Examples of possible inputs are demographic trends (Subtasks 2.1.7/2.2.5), economic expansion (Subtasks 2.1.8/2.2.6), and simulated hydrologic changes (Subtask 3.1.1, Task 3.2). Qualitative insights into consequences of projected developments represent valuable feedback to scenarios to be created in Task 2.2. Such insights can also serve as input to the pathways (Subtask 5.1.1) for the decision-analytic framework (Task 5.2) or the Negotiation Simulation Lab (Task 6.1), in which stakeholders will discuss diverse pathways. Coupling the social models with the governance models (Task 4.2) through related variables in both models (e.g. population (growth)) supports the identification of leverage points for targeted interventions in the social-ecological system: if the social model indicates negative impacts resulting from certain developments, the governance model shows governance instruments (laws and policies) to deal with these developments.

2. METHODS AND DATA COLLECTION

To link the shared expertise of the stakeholders in the basin, a participatory modelling approach was used. Participatory modelling in this case involved the development of mental maps through interviews (details for both basins are described in Sections 3 and 4). Mental maps represent the view of a person on a certain topic. In the case of the DAFNE social model, it required a 60-minute interview with individual stakeholders, a large sheet of paper and post-it notes. The results of each individual interview were then analysed and combined into one overall model, which will ultimately contribute to the DAFNE decision framework.

2.1 PARTICIPATORY MODELLING: ELICITING INDIVIDUAL MENTAL MODELS

The objective of participatory modelling is to identify links between causes and effects as represented in the simple example of the effects of rainfall below. Two elements are connected with an arrow from the cause to the resulting consequence. The polarity or direction of the effect is specified: a plus '+' indicates that if the cause increases, the consequence will also increase and if the cause decreases, the consequence will decrease. A minus '-' indicates that if the cause increases in magnitude, the consequence will decrease. If the cause decreases, the consequence will increase. In the example below: As rainfall increases, soil fertility increases. On the other hand, drought decreases when rainfall increases. This simple example illustrates the idea behind the development of causal loop diagrams (CLDs). Such causal loop diagrams can be used to gain insights into complex, dynamic and interconnected issues; and to communicate those insights (Tip, 2011). As part of system dynamics, causal loop diagrams have been developed in many areas, e.g. water resources management (Winz et al., 2009). In the following section, we demonstrate how CLDs are developed (based on Vennix, 1996).

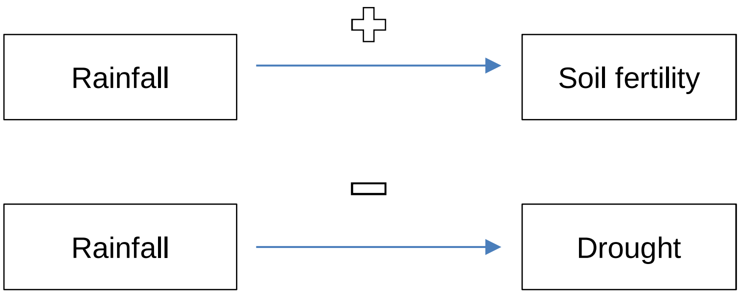

Figure 1: Example illustrating the idea behind causal loop diagrams

This simple example illustrates the idea behind the development of causal loop diagrams (CLDs). In the following section, we demonstrate how CLDs are developed (based on Vennix, 1996).

The interviewee is guided by the interviewer throughout the process and receives advice if necessary. Based on the problem variable, the mental map shows causes, consequences, and interlinkages between the elements (**Error! Reference source not found.**).

Causes	Problem variable	Consequences
	X	

Figure 2: Elements of causal loop diagrams (based on Vennix 1996)

The interviewee is asked to define causes of the problem and to connect them with the problem variable. These causes do not necessarily have to influence the problem directly but can also be an indirect cause. The causes are then connected with each other to identify relationships if necessary (**Error! Reference source not found.**).

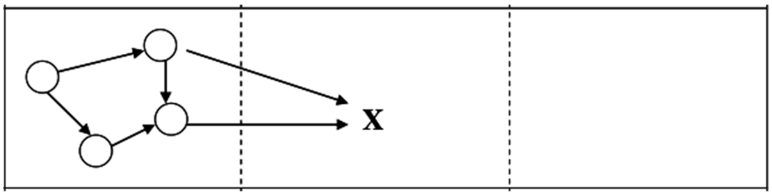

Figure 3: Identify causes influencing the problem variable (based on Vennix 1996)

The same procedure is conducted regarding the consequences of the problem. As before, it is up to the interviewee to identify the consequences and to structure their relationships with links (**Error! Reference source not found.**).

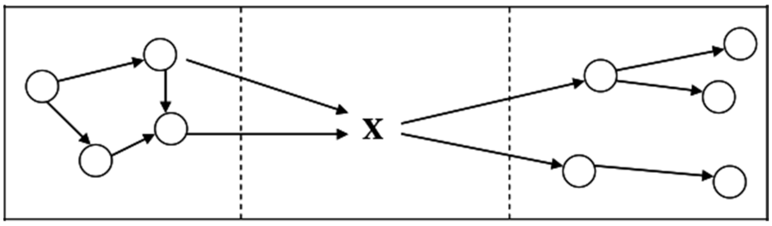

Figure 4: Identify consequences related to the problem variable (based on Vennix 1996)

In a final step, the interviewee is free to draw links between the consequences and causes (**Error! Reference source not found.**).

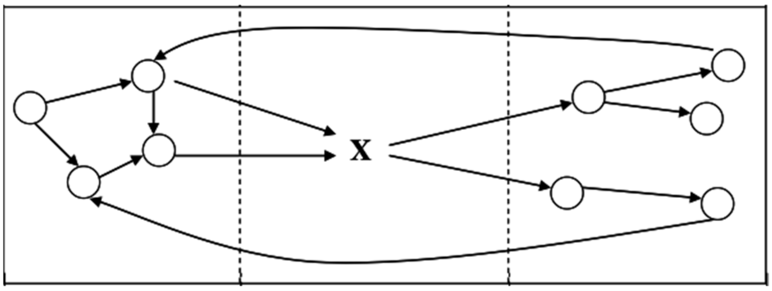

Figure 5: Identify feedback loops between consequences and causes (based on Vennix 1996)

During the interviews for the Omo-Turkana and Zambezi social models, the interviewees were asked to draw direct and indirect links reflecting their understanding of connections in the W-E-F nexus and then identify the polarity (positive or negative effects – see description at the beginning of this section). During the modelling process, the interviewees were free to insert other social, cultural, and demographic issues. The interviews were recorded for subsequent verification of the statements and outcomes.

All of the models were digitized and compared with the recorded interview. Then, these digitized models were sent to the interviewees to confirm the outcomes, insert missing information, make corrections, and obtain their final feedback.

2.2 STAKEHOLDER SELECTION

Stakeholder analysis combines the elements of selecting and then categorizing actors which hold a stake in the system to be studied based on different attributes such as power, interest, role, and legitimacy (Inam et al., 2015). In the DAFNE project, a stakeholder is defined as "anyone who has an interest or stake in the project process or result or holds the ability to influence the outcome of the project" (van Bers, 2018: 4). There are many different tools and techniques which can be applied in the process of stakeholder analysis and selection. The approach chosen for the social model development was a top-down method which builds on an analysis of the positions of stakeholders in the given system and the context in which they are embedded (Hare and Pahl-Wostl, 2002). It builds on the actor analysis conducted in WP 6. Criteria for the selection of stakeholders included the type of stakeholder organisation, scale, sector, function, interest, expertise, resources, and level of engagement (van Bers, 2018).

For the Zambezi model, stakeholders for the interviews were identified in a joint process with the local DAFNE beneficiary UNZA and selected through a combination of brainstorming and a review of the results of the stakeholder analysis undertaken in Task 6.2. The resulting stakeholder list included individuals representing the W-E-F sectors in their line of work for the whole basin and for the Kafue Flats sub region, identified as an area suitable for more in-depth analysis in the project. The selected stakeholders were from governmental and non-governmental organisations and the private sector. Furthermore, web-based research was undertaken to identify more relevant stakeholders. Based on that information, the preliminary list was reviewed, and a final list was prepared. The stakeholders were all situated in Zambia. Ten stakeholders, representing the three sectors, were interviewed: two representatives of NGOs, two from the energy sector, four from the water sector, one from a government ministry concerned with food, and one representative from the food sector.

For the Omo-Turkana model, criteria for the selection of stakeholders for the interviews involved the type of stakeholder organisation, scale, sector, function, interest, expertise, resources, and level of engagement (van Bers, 2018).The final stakeholder selection was then made by the local DAFNE beneficiaries WRLC and ACCESS, which gave their careful consideration to the differing political dynamics in the Omo-Turkana basins. The selection process was underscored by the principle of involving stakeholders from different types of organisations, e.g. non-governmental organisations (NGOs), ministry representatives, private businesses, and independent consulting. Another principle was to involve different knowledge pools among the stakeholders, e.g. representing water, energy or food sector or focusing on social or environmental issues. The distribution of knowledge pools among the stakeholders selected for the Omo-Turkana model is displayed in **Error! Reference source not found.**.

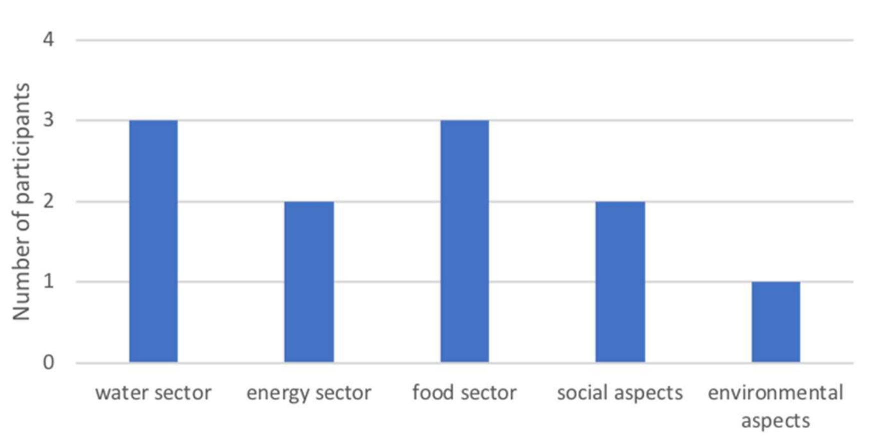

Figure 6: Knowledge pools of the selected Omo-Turkana stakeholders

Once the selection of relevant stakeholders was completed, the stakeholders were contacted to join the participatory modelling process. They received an invitation letter for an interview as well as a description of the DAFNE project and the methodology.

2.3 Analysis of results and merging of individual models

In order to aggregate the perspectives of the interviewees and arrive at an overall model, individual CLDs are merged. This requires analysing, comparing and subsequently merging the individual diagrams. In the case of the Zambezi model, the most comprehensive individual model among the ten diagrams was taken as the starting point, then the results of the other diagrams were systematically compared and integrated into it. In a review of the resulting overall model, the redundant elements were removed. A detailed description of the process of merging individual CLDs for the Zambezi model can be found in Appendix 1. For the Omo-Turkana model, all specificities are described in chapter 4.

3. SOCIAL MODEL FOR THE ZAMBEZI

During the interviews for the Zambezi model, the interviewees were assisted by the interviewer with a few predefined social, demographic, and cultural (SDC) variables: population growth, access to water and/or food, displacement, urbanisation and agricultural practices. These variables had been identified on the basis of the result of the first DAFNE stakeholder meeting in the basin and refined with the help of feedback from WP 4 partners (during two Skype meetings). The predefined variables were offered to the participants if needed and served to stimulate their thinking in how SDC issues are related to the W-E-F nexus. After completion of the interviews, the diagrams were digitized and sent to the respective interviewee. Since only one interviewee responded, the subsequent procedure was adapted: the individual CLDs were merged into one, then the merged overall model was validated and improved in a discussion with stakeholders within the scope the DAFNE Negotiation Simulation Lab (NSL) meeting in Lusaka (Zambia) in September 2017. The individual models and details of the process are documented in Appendix 1. Appendix 1 also describes more approaches to analysing the model than mentioned within the body of this report. In the following section, we focus on the main results, i.e., the merged model and its analysis.

3.1 Social model and description

The model that resulted from combining the interview results is presented in **Error! Reference source not found.**. Key elements of the individual models that were integrated into this include:

population growth (selected from five participants as the starting point), **access to water and/or food** (chosen by four stakeholders), and **health**, which had not been one of the predefined variables and was chosen by one participant. Those participants who identified population growth or access to water/food as a starting point were able to easily connect these issues to W-E-F variables. In the case of human health as the starting point, the direct causes and consequences were linked to other SDC issues.

Several linkages were identified by more than half of all interviewees. Four linkages were mentioned seven times:

- more deforestation leads to more erosion,
- more erosion causes more sedimentation,
- more water availability leads to more irrigation, and
- more irrigation leads to more food production.

Furthermore, five linkages were mentioned six times:

- population growth leads to a higher demand for energy,
- a higher demand for energy causes deforestation,
- population growth leads to a higher demand for water,
- more hydropower leads to increasing water availability, and
- more irrigation leads to decreased water availability.

In all cases, the interviewees had the same opinion concerning the polarity. With a total number of 56 links in the final model, 16% of the links were mentioned by more than half of all participants.

The 16 stakeholders who participated in the validation of the merged model represented organisations from all three W-E-F sectors. They did not include any of the persons that had been interviewed to develop the individual models. The participants of the validation exercise could provide comments on the merged model and could question and – if generally agreed to by all participants – change specific links. The participants were then invited to weight the links in the model. The weighting process was limited to strong and normal links. The participants placed a red dot on single links to mark them as a strong connection. To make the confirmation and weighting process less complex, the merged model was reduced to those links that had been mentioned more than once. The merged model contained 34 variables and 56 linkages. During the weighting and validation process, four links were questioned, and two new variables (hunting/fishing and mining) and seven new links were identified. Some of these are reflected in the photo below (**Error! Reference source not found.**) taken during the validation process. According to the weighting process, 23 links were considered as strong (red dots).

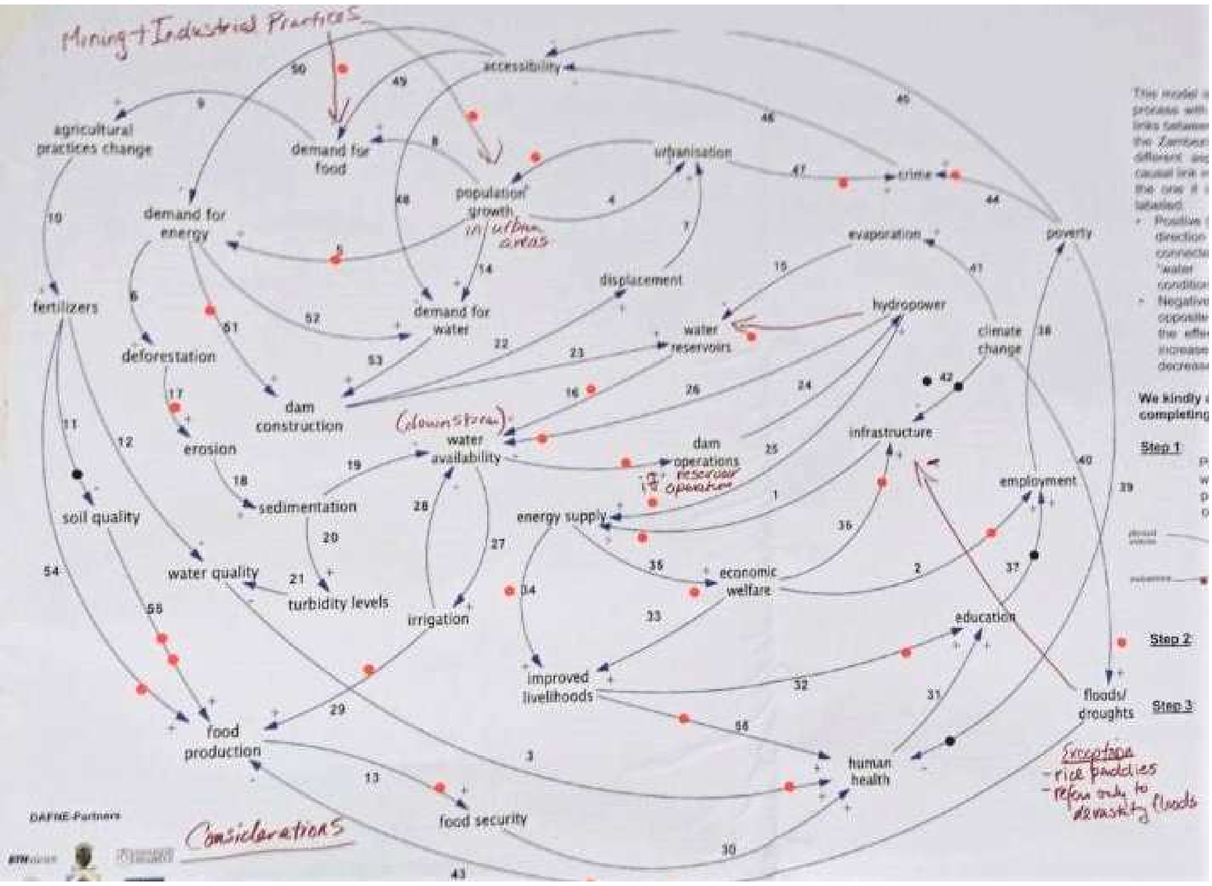

Figure 7: Validation of social model for the Zambezi basin

The final merged and validated model displayed in **Error! Reference source not found.** reflects the consolidated view of the ten individual participants and the 16 stakeholders who participated in the validation process during the NSL in Lusaka. It reflects diverse knowledge on the Zambezi basin and the regional W-E-F sectors. Based on the validation exercise, the final model includes new variables and links. It also highlights connections with strong perceived impacts and those links that were questioned.

As a consequence of the inclusion of new links during the validation, three direct connections between two variables may be removed because their effect is reflected by two consecutive links:

- The connection between population growth and demand for energy may be removed because of a new link between demand for food (impacted by population growth) and demand for energy.
- The connection between hydropower and water availability may be removed because of a new link between hydropower and water reservoirs (with an impact on water availability).
- The link between climate change and infrastructure may be dropped because of a new link from floods/droughts (which are impacted by climate change) to infrastructure.

All direct connections that may be removed have the same polarity as the two consecutive links. Therefore, replacing these connections has no effects on system behaviour.

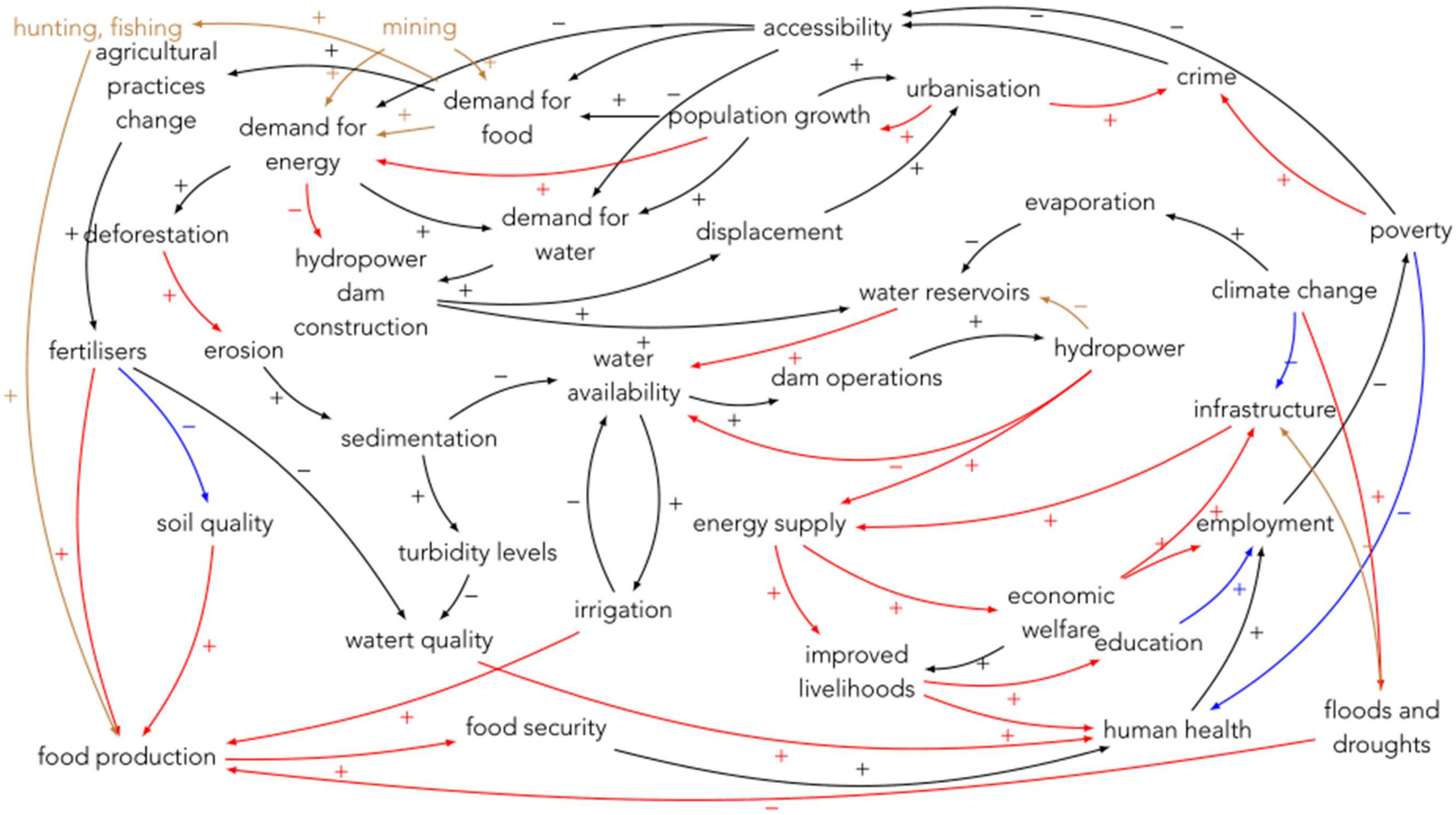

Figure 8: Validated model for the Zambezi basin. Brown arrows: newly mentioned links and variables; red arrows: links with strong perceived impact; blue arrows: links which were doubted.

3.2 KEY FINDINGS AND DISCUSSION

The aim of covering all relevant backgrounds according to Inam et al. (2015) was achieved as stakeholders of every W-E-F sector and NGOs as well as environmental organisations with detailed background knowledge on SDC issues were interviewed. Another aim was to cover the required basin-wide scale. This aim was only partly achieved. The fact that only stakeholders from Zambia were interviewed limits the range of viewpoints and might lead to disregarding differences in the Zambezi river basin. It should be emphasized that the variables and links (positive or negative) that have been identified are the perspectives of the stakeholders. No attempt has been or should be made by the interviewer to influence these outcomes.

The final version of the CLD includes two source variables (with outgoing arrows only): mining and climate change. The model contains no sink variables (only incoming arrows). All the other variables are transmitter variables, which receive and emit impulses to their neighbour variables.

In total 40 reinforcing and 26 balancing feedback loops can be identified in the social model for the Zambezi basin; their length varies between one and 15 arrows. The shortest loops are those between population growth and urbanization (which have positive feedback on one another) and between water availability and irrigation (an increase in water availability leads to an increase in irrigation, which in turn reduces water availability). The short length of the loops indicates a direct and rather strong reinforcing or balancing relationship between these factors, respectively.

Another exemplary reinforcing feedback loop is that of increases in energy supply increasing economic welfare, which leads to better infrastructure, which in turn has a positive impact on the energy supply. All the links between these three factors were identified as having an especially strong impact in the validation of the model.

A reinforcing feedback loop including two of the factors mentioned as particularly important SDC issues is: A stronger trend towards urbanization leads to an increase in population growth, which causes higher demand for water. This is an incentive for the construction of more hydropower dams, leading to more displacement and thus growing urbanization.

In the balanced loops, the most frequently included SDC issues are poverty and employment (24 times in 26 loops), followed by water availability and accessibility (22 times in 26 loops). Accessibility was the factor most frequently found in reinforcing loops (35 times in 40 loops), followed by demand for energy (32 times) and poverty and employment (30 times). Their strong presence in reinforcing feedback loops emphasizes their important contribution to the overall dynamics in the social-ecological system in the Zambezi basin. Interestingly, deforestation, sedimentation, and erosion where factors quite frequently appearing in reinforcing loops (28 times each), but not in balancing loops at all. The testing of the final CLD revealed that, on the whole, the expectations of the participants could be reproduced by the model.

4. SOCIAL MODEL FOR THE OMO-TURKANA

For the Omo-Turkana case study, a social model similar to the one for the Zambezi was developed. Additionally, the models of the interviews in Kenya and Ethiopia, were merged to analyse in how far the perspectives in both countries diverge.

4.1 DATA COLLECTION

The interviews with the Omo-Turkana stakeholders were conducted during a two-week research stay in March 2018 in Nairobi and Addis Ababa. The interviewer visited the stakeholders in their offices to conduct individual interviews of about 45-60 minutes. Besides the interviewer and the interviewed stakeholder, a third person was present to help with translation in the case of language problems. This person also introduced the interviewer to the interviewee before the interview. Table 1 lists the organisations from which participants were interviewed in both countries. In total, nine stakeholders were interviewed – four from Kenya and five from Ethiopia.

Table 1: Organisations interviewed for the Omo-Turkana model

Ethiopia	***Kenya***
Ministry of Agriculture and Natural Resources	*National Environmental Management*
Ministry of Culture and Tourism	*State Department of Livestock*
SisayTesfaye PLC	*Pastoralist Development Network of Kenya*
Ministry of Water, Irrigation, Electricity (two different departments were involved)	*Self-employed, independent consultant*

The interviews were conducted using the basic scheme from Vennix (1996) presented in chapter 2, which was adapted to the context of the research. The interviewee was first asked to prioritize the SDC variables concerning how important and impacting they are in the Omo-Turkana basins. This was done to see how stakeholders with different perspectives value these issues in a common or different way. The issues prioritized as causing the most stress were then used as the initial starting point of the CLD (problem variable).

Based on previous stakeholder meetings in the DAFNE project, a list of potential issues (e.g. SDC issues, water, energy, or food issues) was developed, which stakeholders could select and include in the CLD. This list was given to them as a guide for building the model to overcome difficulties of getting started. During the interview, the interviewees had the option of adding further variables if they felt something important was missing in the presented list. Table 2 lists these predefined variables.

Table 2: Predefined variables for interviews for the Omo-Turkana case study

SDC variable	**Water sector**	**Energy sector**	**Food sector**	**Further variables**
Health	Water withdrawal	Oil exploration/production	Demand for food	Land degradation
Education	Rainfall	Energy demand	Food production	Soil quality
Population growth	Water quality	Renewable energy (solar, wind)	Food security	Deforestation
Poverty	Lake level of lake Turkana	Hydropower	Fish stock, livestock	Relocation of indigenous people
displacement	Changing downstream pattern	Energy production/supply	Fertilizers	Climate change
Conflicts	Irrigation	Power deficits	Subsistence farming	Competition for land
Changes in livelihood	Water demand	Power lines	Commercial agriculture	Infrastructure
	Water availability			Economic development
	Dam construction/ operation			Land use change
	Droughts/ floods			

After the interviews, the individual models were digitized and transformed into a network for better visualization. As evidence of accuracy, these digital models were sent again to the participating stakeholders for validation and to ask for necessary corrections (four out of nine participants provided their agreement or corrections). Since not every participant gave his/her confirmation of the CLD created, the process of merging together the interviews was not completely based on confirmed models.

All individual models were then merged into one overall social model. Additionally, the models of the interviews in each country were merged. This was done to analyse in how far the perspectives in Kenya and Ethiopia converge or diverge. Merging was done according to Inam et al. (2015). First, variables of identical meaning were summarized. An analysis of this process can be found in section 4.2. Then, based on this summarization, the remaining variables were collected in a new model to which links from all interviews were added then.

4.2 SOCIAL, DEMOGRAPHIC AND CULTURAL ISSUE ANALYSES

Table 3 presents an overview of the SDC issues prioritised as most pressing by the interviewees in the beginning of the CLD modelling process. It allows a comparison between the different perspectives in both countries. Throughout all interviews, poverty was the most mentioned element. In Ethiopia, every interviewee considered it to be one of the most critical factors. In Kenya three of four interviewees did so, too. Moreover, it is interesting to see the issue of conflicts being highly relevant in the Kenyan interviews and, on the other hand, changes in livelihood being an exclusive choice for the Ethiopian models.

Table 3: SDC issues prioritised as most pressing in Ethiopia and Kenya

SDC issue	Ethiopia	Kenya
Poverty	5	3
Migration	2	1
Displacement	1	2
Conflicts	2	3
Changes in livelihood	2	0
Health	1	2
Education	1	0
Population growth	0	1

Table 4 shows all the SDC issues and the number of times they were used in the models. It is noticeable that quite a few SDC issues are shared between both countries and models, for example, poverty, migration, health, conflicts, urbanization, and food security. By contrast, three SDC issues (jobs, indigenous people craft/knowledge/culture, and social-multi-ethnic-society) were exclusively used in Ethiopian models. On the other hand, the issue of “militarization” was used exclusively in Kenya. Only four of 15 issues were mentioned less than three times, which shows the great overlap of SDC issues mentioned in both countries.

Table 4: SDC issues identified in interviews in Ethiopia and Kenya

SDC issues	**Times used in Ethiopia**	**Times used in Kenya**
Poverty	5	3
Changes in livelihood	5	-
Human-wildlife-conflicts	1	1
Jobs/ job creation	3	-
Indigenous people craft/ knowledge/ culture	1	-
Migration	3	3
Health	3	3
Education	2	1
Conflicts	4	3
Urbanization	4	3
Population growth	2	2
Social-multi ethnic society	1	-
Food security	4	2
Displacement	2	3
Militarization	-	1

Throughout the models, the SDC issues that were prioritised at the beginning also represent the core of the CLD. To analyse their role,

Table 5 and Table 6 show in- and out-degree centralities (McGlashan et al. 2016) of the prioritised SDC issues for Ethiopia and Kenya, respectively, and of human-wildlife conflicts. Although the latter variable had not been classified by the interviewees as one of the most pressing SDC issues, it turned out to play an important role in the case of Ethiopia. The degree centralities here were calculated to gain information on the centrality and embeddedness of these issues both in individual CLDs and merged CLDs for both countries. As shown in Table 4 above, poverty was mentioned in the majority of interviews as the most pressing variable. Also, the tables show how strongly poverty depends on various other SDC issues in the two models: for both countries, it is more influenced by other issues than it influences other issues (in_deg > out_deg) and possesses by far the largest total degree centrality.

In general, most of the SDC issues prioritized in the beginning of the interviews reveal a higher degree-centrality than the average degree centrality of the other variables in the CLD. Moreover, most of them show a greater in- than out-degree centrality. A possible explanation is that the stakeholders regarded the prioritized SDC issues as significant matters of importance by themselves and the investigation of their causes was therefore regarded as more important than their further consequences. It is noticeable that quite a few SDC issues are shared between both countries in the models.

Table 5: Properties of SDC variables in Ethiopia

Variable	In-degree centrality (in_deg)	Out-degree centrality (out_deg)	Total degree centrality (in_deg + out_deg)
Poverty	55	11	66
Changes in livelihood	15	11	26
Human-wildlife conflicts	5	1	6
Migration	10	7	17
Health	10	2	12
Education	7	3	10
Conflicts	5	1	6
Population growth	1	4	5
Displacement	2	3	5

Table 6: Properties of SDC variables in Kenya

Variable	In-degree centrality (in_deg)	Out-degree centrality (out_deg)	Total degree centrality (in_deg + out_deg)
Poverty	23	7	30
Changes in livelihood*	-	-	-
Human-wildlife conflicts	2	0	2
Migration	8	6	14
Health	6	3	9
Education	3	2	5
Conflicts	11	7	18
Population growth	4	3	7
Displacement	4	1	5

*not included in the Kenyan model

4.3 SOCIAL MODEL AND DESCRIPTION

To identify the differences in the perspectives of Kenyan and Ethiopian stakeholders, the two models of the two countries were merged from the interviews in each country. Because of the various differences in perspectives and causal relations, the creation of national models was helpful to compare differences.

The merging of individual CLDs was done according to Inam et al. (2015) in two steps. First, variables of identical meaning were summarized. Secondly, based on the variables defined in step one, links in the individual CLDs were compiled in a new model.

4.3.1 National models

While merging the individual CLDs into a joint model for each country, similar causal links were summed as proposed by Inam et al. (2015). In the individual Ethiopian models, there was a total of 127 links, of which 38 were mentioned at least twice. Three links were mentioned in four models:

- more migration leads to more poverty,
- more food production leads to less poverty, and

- more jobs lead to less poverty.

It is also important to note that there were 110 positive and only 55 negative links in the case of the Ethiopian models.

In the four interviews conducted with Kenyan stakeholders there was a total of 136 links, of which 87 were noted positive. Here, 27 links were mentioned at least twice in the interviews. The following links were mentioned most often:

- more oil exploration leads to more oil spills,
- more oil exploration leads to more displacement of people,
- more oil exploration leads to more land erosion,
- more dam construction leads to more water scarcity, and
- more deforestation leads to more land erosion.

To allow a clearer visual representation, the national models were simplified. Results can be seen in Figure 9 for Ethiopia and Figure 10 for Kenya. These models include the causal links mentioned most often and issues which were mentioned at least twice. For simplification of the models, some elements were merged with others or deleted from the visualization. Elements with different wordings that describe the same phenomenon or its inverse (e.g. health and diseases) were regarded as one element for the merged CLD. Furthermore, elements only possessing links going in or out were ignored because of their lower level of importance for system dynamics and the clearer visual representation.

Both national models differ in key issues which result from different socio-economic and environmental contexts in the two countries. For example, Ethiopian stakeholders mentioned migration that took place in a very different context as compared to migration mentioned by Kenyan stakeholders. Therefore, merging both migration elements in an international CLD would only lead to a neglect of the differences between the key issues in the two countries.

However, the interview outcomes from Ethiopia and Kenya also revealed similarities in several aspects. They share most elements influencing SDC issues such as poverty, conflicts and migration (even though the specific context may vary). Also, there are identical dynamics revolving around environmental issues, such as causes of land erosion and climate-related problems. Regarding the SDC issues, poverty was identified in the majority of interviews as the most important issue. Both models share almost the same set of SDC issues with a few differences in prioritization. Conflicts represent the SDC issue that differed most in the two countries. It is a more pressing issue in Kenya according to its prioritization.

Large differences appear in the dynamics created by dam construction. As dam construction and its consequences is one of the most crucial political issues between the two countries according to some of the stakeholders, different outcomes of dam construction appear in each national model. Kenyan stakeholders, who represent the downstream basin, relate dam construction to four main factors: water scarcity, pasture availability, water withdrawal and commercial agriculture. Then, in the Kenyan model, water scarcity in particular is an important element (with a high degree centrality) impacting, for example, poverty levels or crop production. In this model, commercial agriculture is exclusively influenced (increased) by dam construction. Compared to negative aspects (e.g. higher water scarcity), which show up as consequences in the Kenyan model, a major consequence of dam construction in the Ethiopian CLD is the constant downstream pattern, which is decreasing land erosion and increasing water access. This key difference lies in how both countries representatives evaluate the impacts of dams along the Ethiopian Omo River on the water sector. The in-degree centrality of water scarcity/access is significantly higher in Kenya, which reveals more issues that may put water access for citizens at risk. In addition to the water sector, Ethiopian stakeholders stressed the economic effect of dam construction and related commercial agriculture on the generation of job opportunities and therefore to poverty reduction. Coming back to the Kenyan model, dam construction may rather be associated with an increased level of poverty according to the views of stakeholders.

Further differences can be found in the issue of land scarcity (Ethiopia) and competition for grazing land (Kenya). In both CLDs, this issue is well embedded, however, each national level CLD relates land scarcity to different causes. Land scarcity in the Kenyan case results in displacement (due to floods and oil exploration). Population growth, droughts, land erosion and livelihood changes appear to be the main factors in the Ethiopian context.

Oil exploration is an issue that is exclusively happening in Kenyan territory (for the most part on the northern side of Lake Turkana). Therefore, related consequences for the environment can only be found in the Kenyan model.

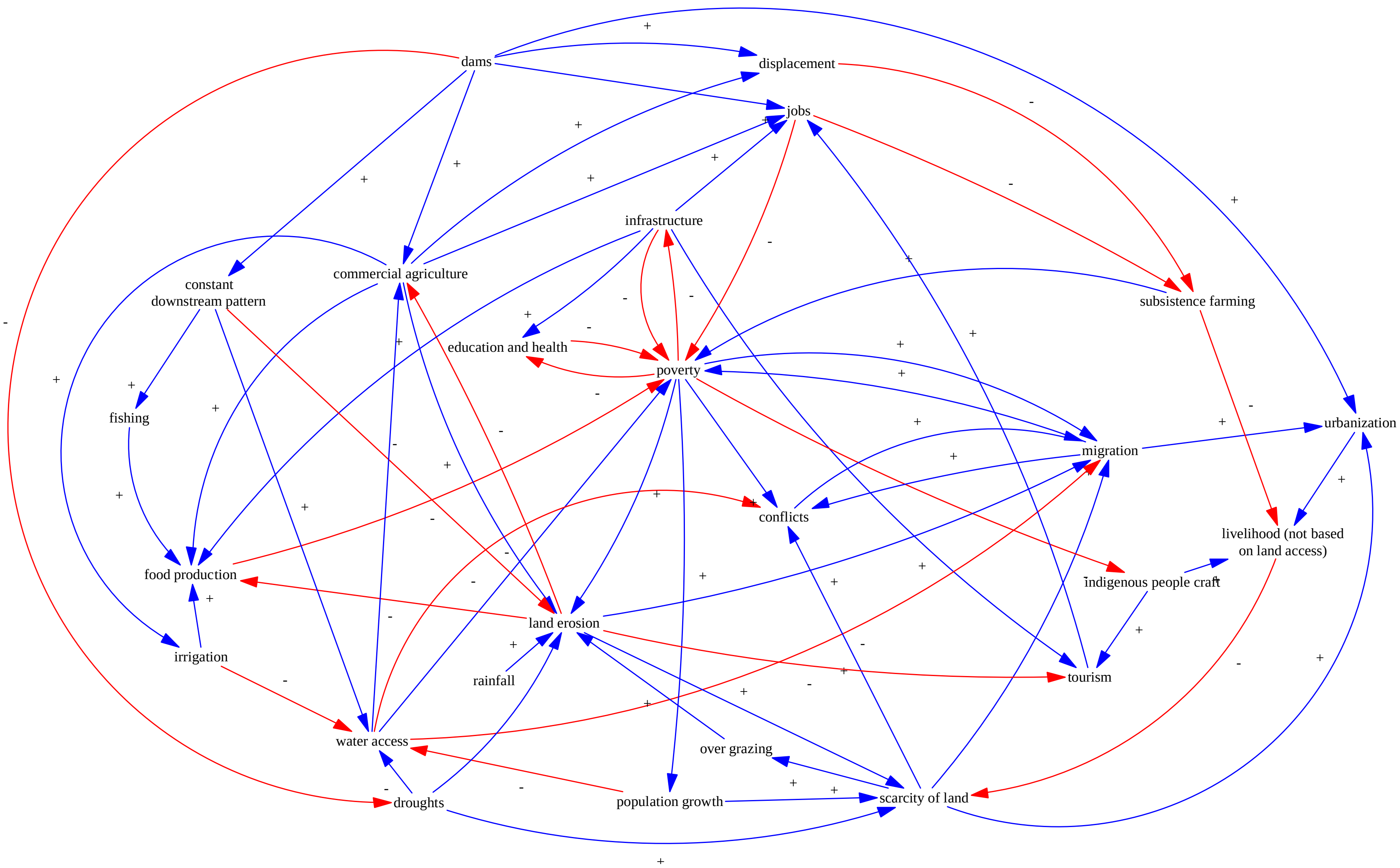

Figure 9: National model Ethiopia. Red arrows (also tagged with „-") indicate negative links, blue arrows (also tagged with „+") indicate positive links.

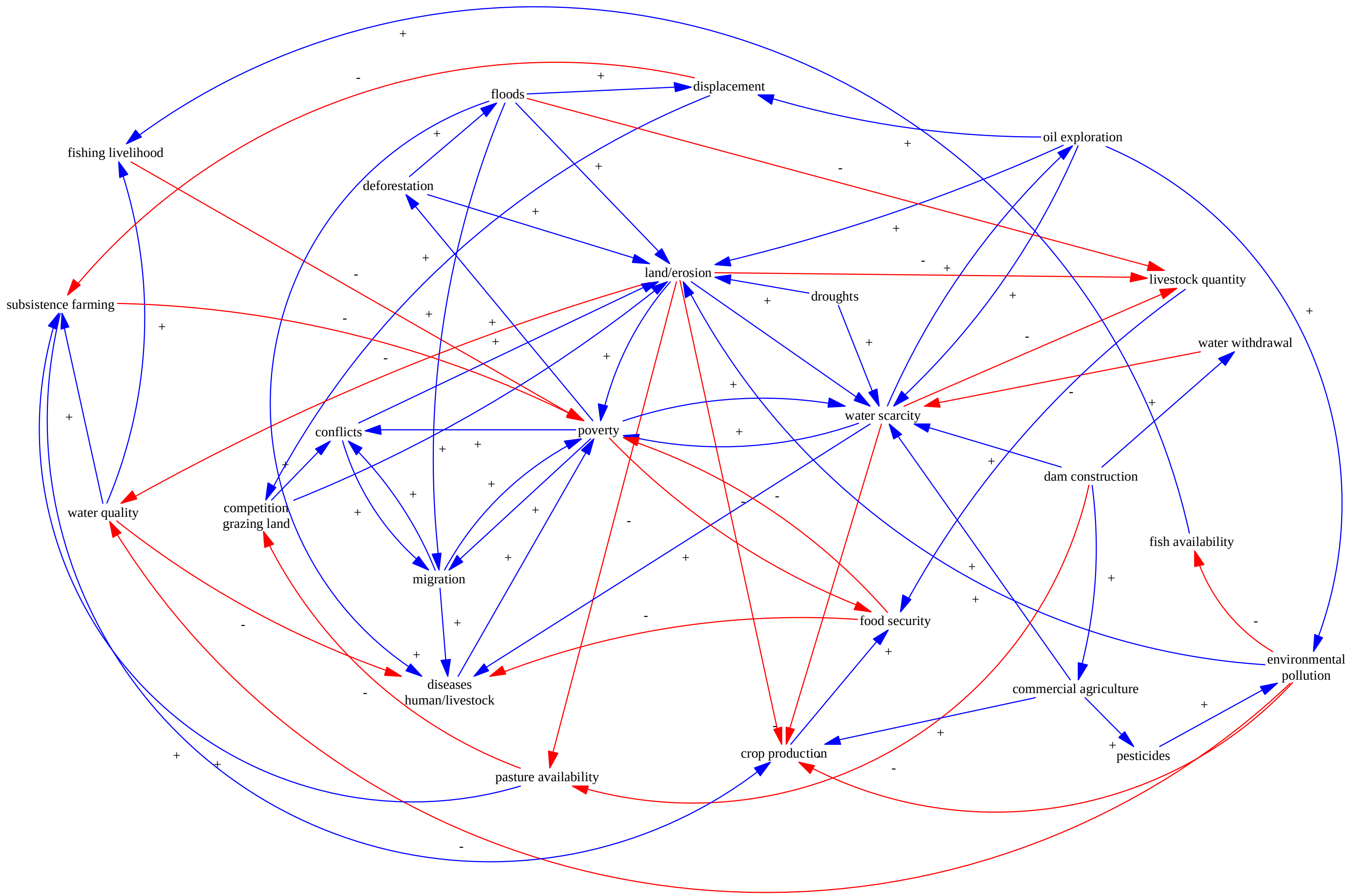

Figure 10: National model Kenya. Red arrows (also tagged with „-“) indicate negative links, blue arrows (also tagged with „+“) indicate posi tive links.

4.3.2 The Omo-Turkana social model

Figure 11 shows the final social model based on the merging of the results of all interviews conducted in both countries. The same methodology applied to the national models was used in the merging process of this model. Hence, as for the national models, this model includes simplifications and does not cover every single variable used to facilitate a clearer visual representation. Nevertheless, it captures every basic thematic scheme. The Omo-Turkana model also displays the differences between the national models: Different types of arrows represent causal links which are included in only one national model. This involves, for example, constant downstream patterns (controlled floods, and oil exploration.

The focus of the research is on the connection of W-E-F variables to SDC issues. As the SDC issues have already been analysed in their prioritization and embeddedness, Figure 12 shows a thematic sub-model of SDC issues. It is based on interviews from both countries and embodies all the named SDC issues listed in

Table 4. Furthermore, the variables “tourism” and “mortality” were added because of their relevance for the system dynamics in offering a high level of connectivity between other SDC issues. The figure stresses the strong interconnection of SDC issues. Again, it points out the aspect of poverty as the most central issue. Furthermore, poverty, migration, and conflicts form a group in which all three elements are connected to each other, and therefore forming a sort of centrepiece in the model. The high density of links in the model emphasizes the complexity in governing and evaluating dynamics in this system. For some causal linkages, there is no clear identification of a positive or negative relationship. The reason is that differences exist between the Ethiopian and Kenyan national models with respect to the polarity of these links, as perceived by the stakeholders. Such links are tagged with a “0” on the related arrow.

After conducting interviews and evaluating the set of variables, they can be grouped into water, energy, food, land, environmental and social variables. The land group was defined as such because there were nine variables based on land-related aspects like availability, access, quality etc. These often relate closely to agriculture and the nomadic livelihood systems in the areas. Merging the variables from both national models, we find 15 food variables (e.g. commercial agriculture, crop production, food security and fish stock), nine from the energy sector (e.g. hydropower production, renewable energy, oil exploration) and eight from the water sector (e.g. water quality, water scarcity, irrigation). The environment group of variables includes issues related to climate (e.g. climate change, droughts, floods) as well as consequences from climatic or anthropogenic action (e.g. deforestation, land degradation, and oil spills). Finally, the largest group is represented by social variables with a total of 20 different variables used.

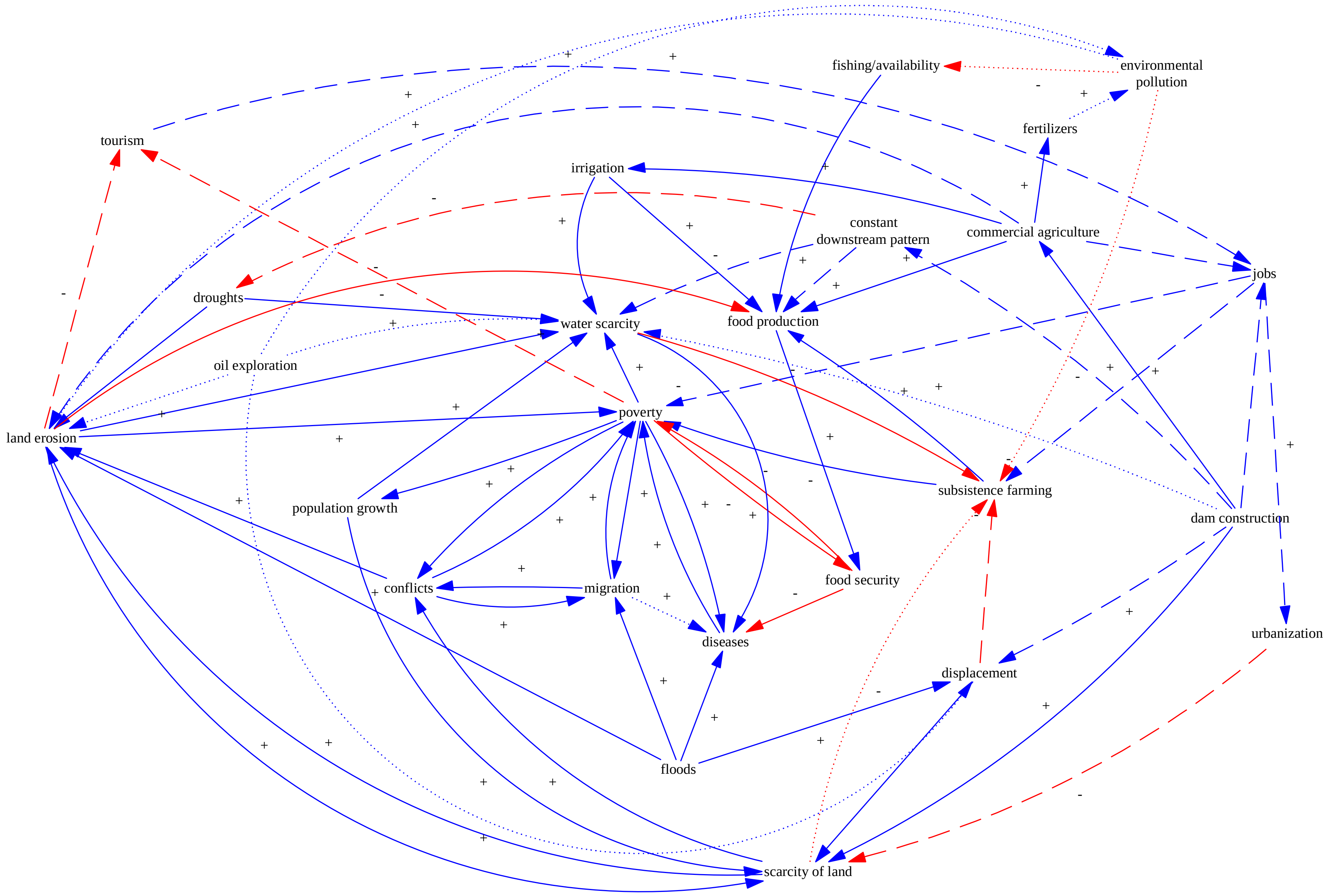

Figure 11: Complete model for the Omo-Turkana basins. Finely dashed arrows refer exclusively to Kenya, coarsly dashed arrows only to Ethiopia.

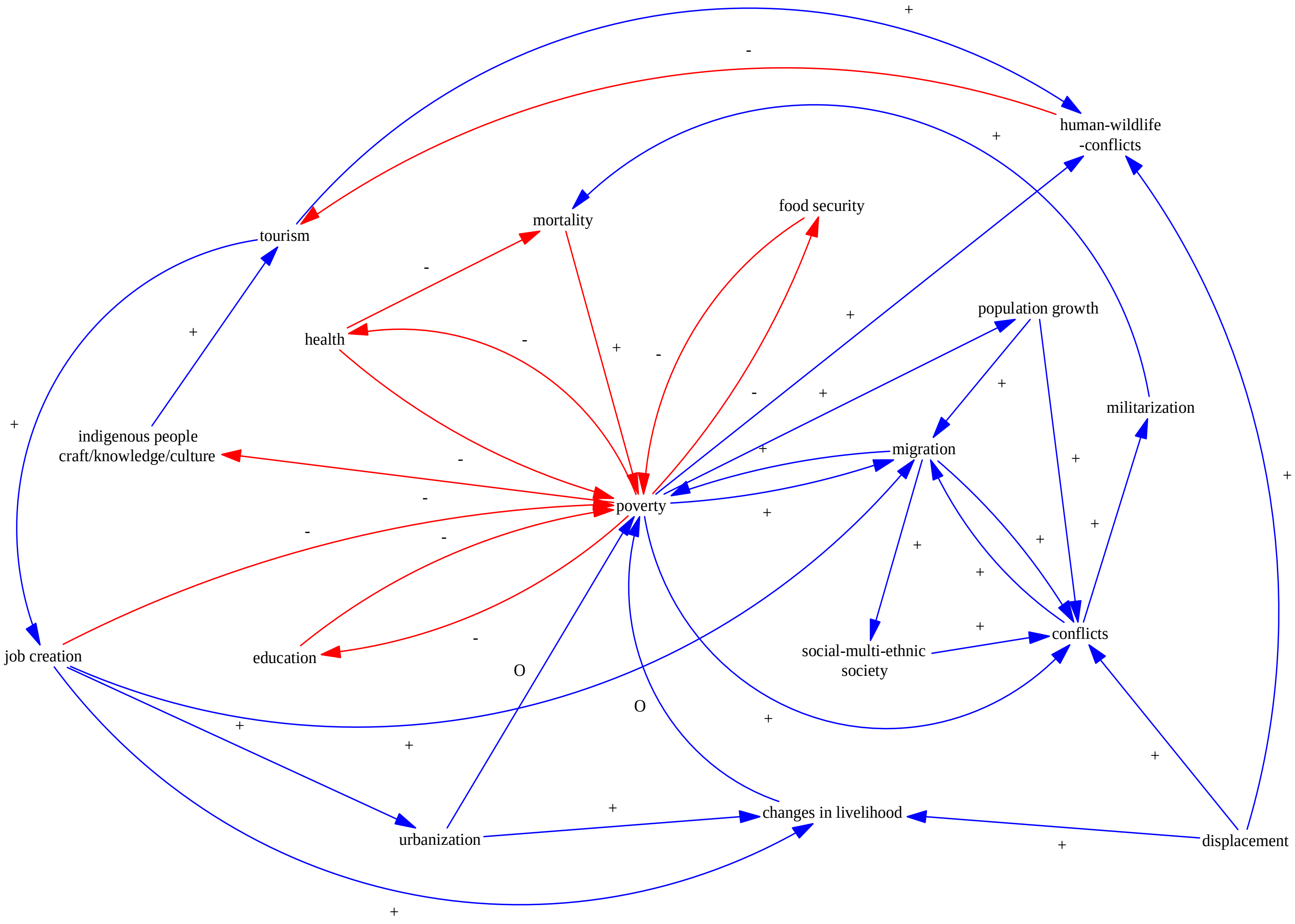

Figure 12: Sub-model of SDC issues for the Omo-Turkana basins. Links that cannot be clearly classified as positive or negative are tagged with “0”.

4.4 KEY FINDINGS AND DISCUSSION

Based on the Omo-Turkana model, we find differences among the interview outcomes between Kenya and Ethiopia. This relates mostly to dam construction resulting in different dynamics of the two models. As already discussed in 4.3.1, from the Kenyan perspective dam construction may lead to more poverty because of increased water scarcity on the Kenyan side. By contrast, Ethiopian stakeholders pointed out the positive impact of the dam by regulating floods to provide a more constant water availability throughout the downstream system, which would have a positive impact on food production and therefore also on SDC issues.

As the SDC thematic sub-model (Figure 12) showed, there is a strong connection and impact among the various SDC issues, with these relations being almost identical between both countries. The analysis of this sub-model revealed the central role of the three interrelated SDC issues of poverty, migration and conflicts, which are influenced by numerous SDC issues and, in turn, have impacts on various other ones.

Furthermore, from the perspective of Kenyan stakeholders, oil exploration influenced environmental and social issues, which were mentioned several times in Kenyan interviews. Because of the spatial scale of this oil exploration, it is only an issue of Kenyan CLDs.

Finally, the complete model for the Omo-Turkana basins exhibits a high degree of complexity characterised by a high density of links and numerous feedback loops in the system.

5. EXEMPLARY APPLICATION OF THE MODELS

To illustrate how the social models for the Zambezi and Omo-Turkana basins help in exploring interlinkages among diverse W-E-F nexus factors and SDC issues, we demonstrate the system dynamics evolving in the context of population growth. A dataset on demographic trends was collected within the scope of DAFNE Subtask 2.1.7. The dataset, originally published by the African Development Bank Group (2015), includes annual population numbers for the Zambezi riparian states as well as for Ethiopia and Kenya in the period 1960-2013. It indicates increasing populations in all countries (Table 7 and Table 8).

Table 7: Development of the population number in the Zambezi basin's riparian states 1960-2013 (based on data from the African Development Bank Group 2015).

Country	Population in 1960	Population in 2013	Population growth (%)
Angola	4,965,988	21,471,618	332
Botswana	524,173	2,021,144	286
Malawi	3,525,127	16,362,567	364
Mozambique	7,647,284	25,833,752	238
Namibia	602,545	2,303,315	282
Tanzania	10,074,490	49,253,126	389
Zambia	3,082,627	14,538,640	372
Zimbabwe	3,752,390	14,149,648	277

Table 8: Development of the population number in Ethiopia and Kenya 1960-2013 (based on data from the African Development Bank Group 2015).

Country	Population in 1960	Population in 2013	Population growth (%)
Ethiopia	22,151,218	94,100,756	325
Kenya	8,105,440	44,353,691	447

5.1 GROWING POPULATION IN THE ZAMBEZI BASIN

Error! Reference source not found. shows that population growth causes urbanisation as numerous people from the countryside move to the cities looking for better job opportunities. Increased urbanisation, in turn, is strongly linked to population growth. This reinforcing feedback loop creates particular development challenges to cities, which need to provide infrastructure and economic opportunities to a rapidly increasing population. Rising crime as a consequence of urbanisation, a link perceived as strong, indicates that cities have not been able to address these challenges effectively so far.

The growth of the population leads to increased demands for water, for food, and finally for energy. These increasing demands pose challenges to the W-E-F nexus because the supply of more water, energy and, food is not only associated with benefits to the population, but it also includes unintended consequences.

- The rising demand for energy and water is strongly linked to the construction of new hydropower dams in the Zambezi basin. A drawback of this development is that dam construction projects lead to the displacement of people in rural areas, which reinforces urbanisation. On the other side, more hydropower dams facilitate more water reservoirs, which strongly improve the availability of water. As a consequence, irrigation in agriculture expands. This has a strong positive effect on food production, which in turn is strongly linked to higher food security. However, irrigation also leads to the reduction of water availability, thereby creating a balancing feedback loop between irrigation and water availability. An increase of water availability through more water reservoirs not only helps to improve food security. Higher water availability also allows more dam operations, leading to the generation of more hydropower. As this has a negative effect on water reservoirs, another balancing feedback loop occurs. The expansion of hydropower is strongly linked to an increase in energy supply. This has strong positive effects related to economic welfare and improved livelihoods.
- Rising demand for energy is also associated with increased deforestation. This leads to more sedimentation. Sedimentation, in turn, has a negative impact on water availability.
- Higher demand for food fosters the change of agricultural practices, which is associated with the use of more fertilisers. While fertiliser use is strongly linked to more food production, it also leads to lower water quality and to lower quality of soils. While the former has a strong effect on human health, the latter strongly impacts the production of food.

5.2 GROWING POPULATION IN THE OMO-TURKANA BASINS

Figure 11 shows that poverty, resulting from the combination of various factors, represents a major driver of population growth in the Omo-Turkana basins. The growth of the population is associated with water and land resources getting scarcer both in Ethiopia and in Kenya.

- A higher scarcity of land is associated with conflicts and land erosion. Rising conflicts lead to more poverty and increased migration. The latter can bring about even more conflicts – a reinforcing feedback loop emerges. In Kenya, increased scarcity of land has a detrimental effect on subsistence farming, which leads to more poverty. Land scarcity is also linked to more land erosion because farmers and pastoralists are forced to use existing land resources more intensively. A reinforcing feedback loop occurs through land erosion triggering further scarcity of land. Eroding land is another reason for poverty, and it increases water scarcity in both countries. Moreover, eroding land reduces food production and increases poverty. In Kenya, the erosion of land leads to environmental pollution, thereby impacting fishing and subsistence farming in that country. In Ethiopia, land erosion has a negative impact on tourism, which jeopardises job opportunities.
- Increased water scarcity has negative impacts on subsistence farming, resulting in decreased food production. This in turn compromises food security, which leads to increased poverty. As poverty increases water scarcity, a reinforcing feedback loop emerges. Another reinforcing feedback loop occurs through water scarcity resulting in an increase of diseases, more diseases leading to increasing poverty, and more poverty reinforcing water scarcity.

6. CONCLUSION

In summary, the approach to developing the social models for the Zambezi and Omo-Turkana basins supported a systematic identification of links between social, demographic and cultural dimensions and issues of the W-E-F nexus. Participatory modelling is an effective and cost-efficient method ~~to~~ for understanding the complexity of interconnected social-ecological systems from the perspective of the stakeholders.

6.1 MODEL UNCERTAINTY AND USE

The presented models are qualitative in nature. Hence, it is not possible to make any claims regarding quantitative model behaviour (quantitative changes of elements). Furthermore, one should be aware of the uncertainty of model elements and interlinkages. Even if combining a number of expert views, it remains an elicitation of personal perceptions of a system, which can hardly be verified. For the Zambezi model, the basis was data collection that took place in Zambia, which represents only one of eight riparian states of the Zambezi River basin. Even though Zambia occupies around 43% of the Zambezi basin, seven countries were not included in this data collection process. Therefore, the collected data could lack country-specific characteristics within the Zambezi river basin. Further interviews with local people who deal with W-E-F issues every day, e.g. people who live by the river as well as farmers and local organisations, might have led to much more specific details, which might have facilitated a more holistic – and also more complex – representation of the system.

The final models reflect important relationships between variables, but they do not reflect the real system perfectly (as no model will do). However, the final models serve as a good starting point to suggest interconnections between SDC and W-E-F issues. They also help to identify possible balancing and reinforcing feedback loops, which may support decision-making processes. Furthermore, it is possible to identify certain risks or key connections within the social-ecological systems of the Zambezi and Omo-Turkana basins. Lastly, social models for both case studies may be of value for the creation scenarios and pathways, for DAFNE's decision-analytic framework, and for the negotiation of various management options among stakeholders within the scope of the NSL, as described in chapter 1.3.

6.2 KEY ISSUES AND LINKS IN BOTH MODELS

Key elements in the Zambezi model were population growth (selected by five participants as the starting point) and access to water and/or food (chosen by four stakeholders). Key linkages between the elements (identified by more than half of all interviewees in both countries) were:

- more deforestation leads to more erosion,
- more erosion causes more sedimentation,
- more water availability leads to more irrigation,
- more irrigation leads to more food production,
- population growth leads to a higher demand for energy,
- a higher demand for energy causes deforestation,
- population growth leads to a higher demand for water,
- more hydropower leads to increasing water availability, and
- more irrigation leads to increasing water availability.

Based on the Omo-Turkana model, differences among the interviews between Kenya and Ethiopia mostly relating to dam construction were found. From the Kenyan perspective, dam construction will lead to more poverty based on a higher level of water scarcity on the Kenyan side. Ethiopian stakeholders pointed out the positive impact of the dam by regulating floods to provide more constant water availability throughout the downstream system, which would have positive effects on food production and therefore also SDC issues. Furthermore, from the perspective of Kenyan stakeholders, oil exploration influenced environmental and social issues. In the interviews conducted with Kenyan stakeholders the most named links were:

- more oil exploration leads to more oil spills,
- more oil exploration leads to more displacement,
- more oil exploration leads to more land erosion,
- more dam construction leads to more water scarcity, and
- more deforestation leads to more land erosion.

In the Ethiopian model, the links indicated most frequently were:

- more migration leads to more poverty,
- more food production leads to less poverty, and
- more jobs lead to less poverty.

Kenyan and Ethiopian interviewees identified many of the same elements influencing SDC issues such as poverty, conflicts and migration. Regarding the SDC issues, poverty was identified as the most important issue. Furthermore, poverty, migration, and conflicts are all closely linked to each other, and therefore form a kind of centerpiece in the model.

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APPENDIX 1: MASTER THESIS WITH COMPLETE ZAMBEZI MODEL, INCLUDING THE MODEL DEVELOPMENT PROCESS

The master thesis of Nils Eikemeier, which provides an in-depth description of the Zambezi social model, has been attached as a separate file to this report.

APPENDIX 2: INDIVIDUAL MODELS AND SUPPORTING DOCUMENTATION FOR THE OMO-TURKANA MODEL

This appendix provides the individual CLDs created during the interviews with Kenyan and Ethiopian stakeholders. They consist of an average of 25 nodes. The average network density (McGlashan et al. 2016) of these models varies strongly between 0.03 and 0.56 with standard deviation of 0.166. Analysing a potential correlation between nodes and density shows no linkage between both parameters (R^2 = 0.125 on a linear regression). Table 9 shows more details on the individual CLDs.

Table 9: Density, links and nodes in individual CLDs

Interview ID	Nodes	Links	Network Density
ET1	26	37	0.56
ET2	18	42	0.13
ET3	37	53	0.03
ET4	26	61	0.04
ET5	21	28	0.06
KEN1	12	15	0.11
KEN2	25	39	0.08
KEN3	32	43	0.04
KEN4	28	65	0.08

In the following figure (13), we provide visual representations of the individual CLDs (Figure 14 to Figure 22). Figure 13 provides an overview of the organisations of the interviewed participants and connects them to an ID, which is provided in the captions of the CLD figures and the table above.

Orgaization	ID
National Environment Management Agency	Ken1
State Departement of Livestock	Ken2
Pastoralist Development Network	Ken3
Independent Consultant	Ken4
Ministry of Agriculture and natural resources	ET1
Ministry of Culture and Tourism	ET2
Sisay Tesfaye PLC	ET3
Ministry of Waterm Irrigation, Electricity	ET4
Ministry of Waterm Irrigation, Electricity	ET5

Figure 13: Organisation IDs

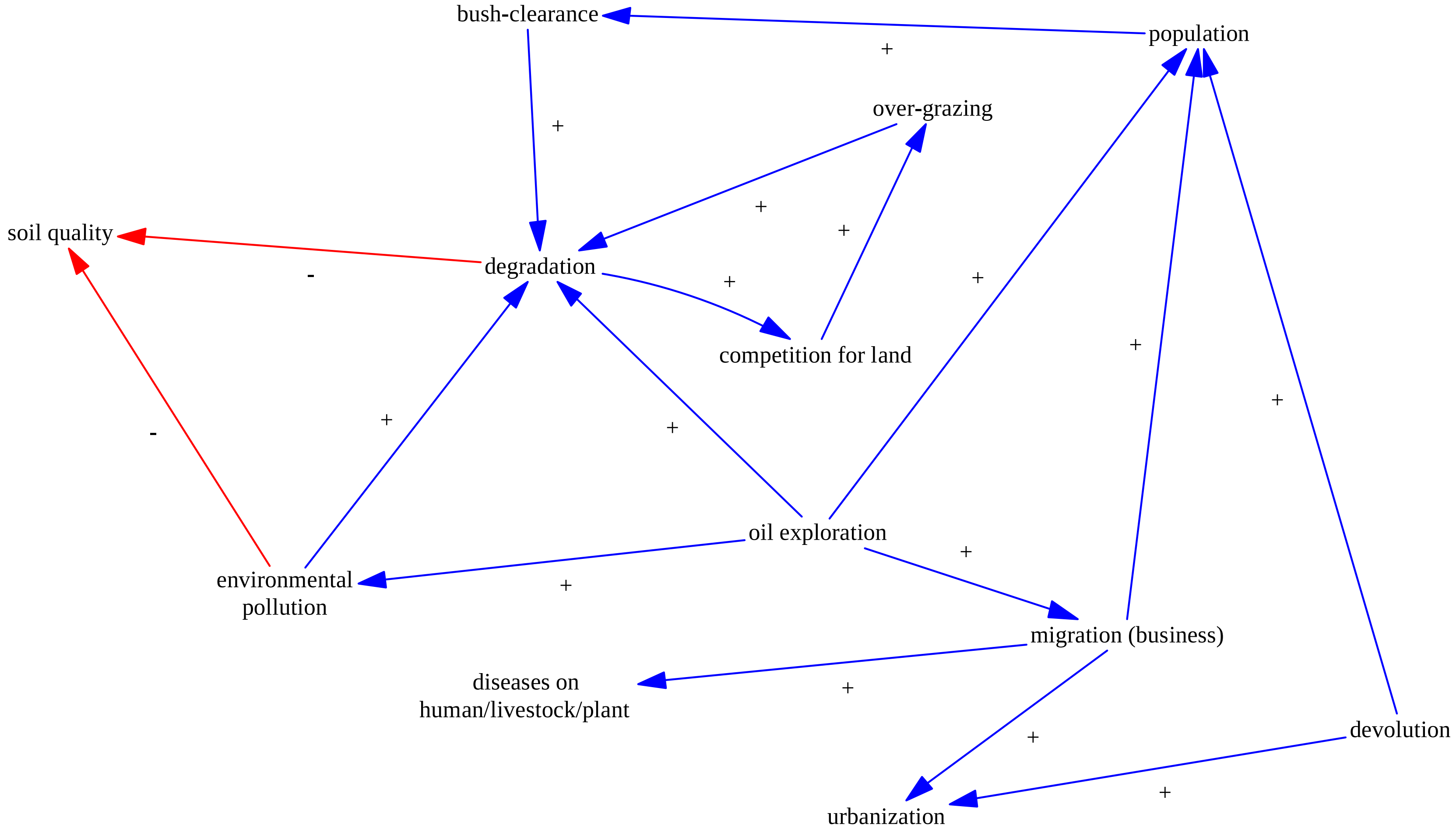

Figure 14: Individual CLD from participant Ken1

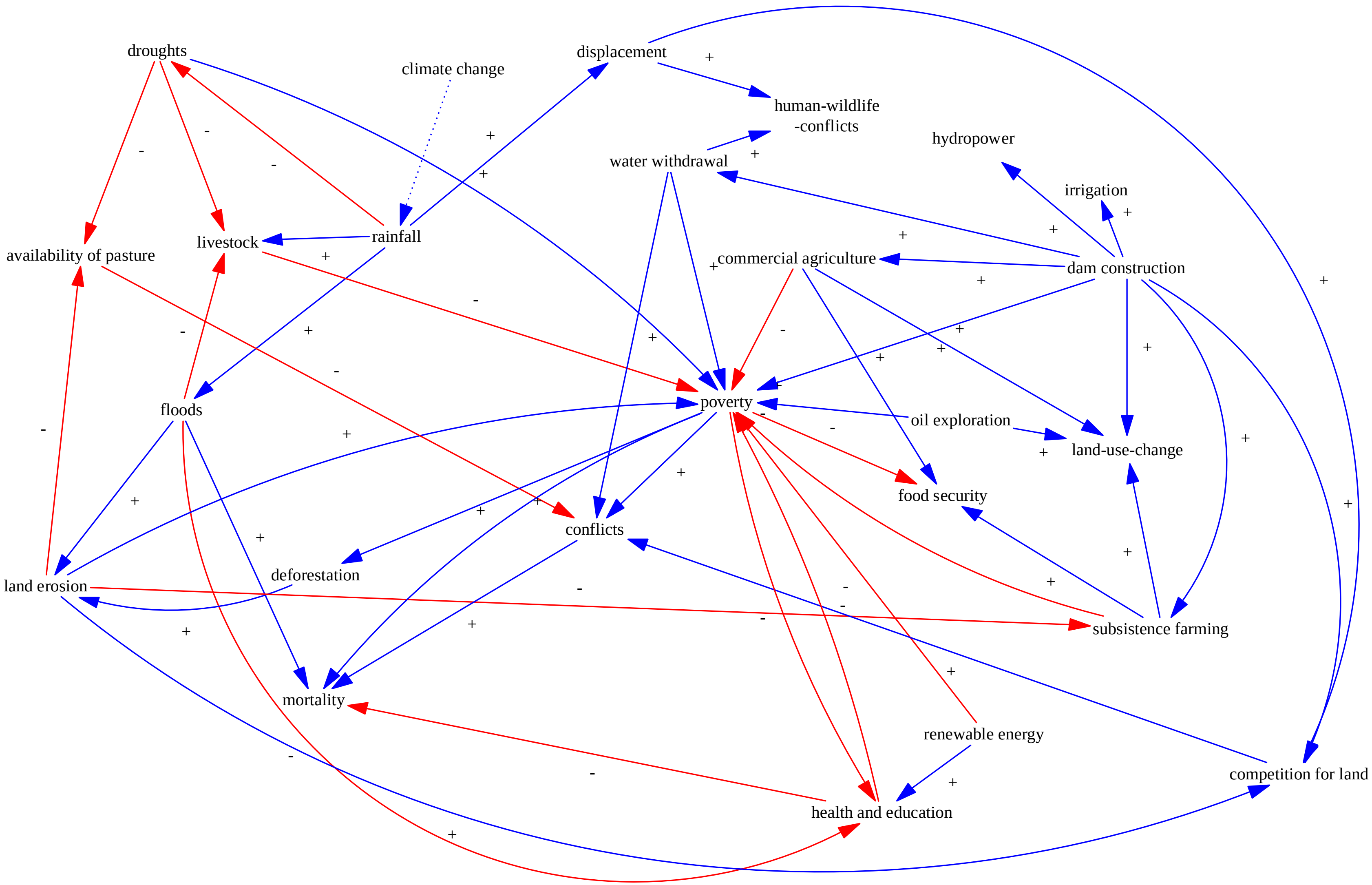

Figure 15: Individual CLD from participant Ken2

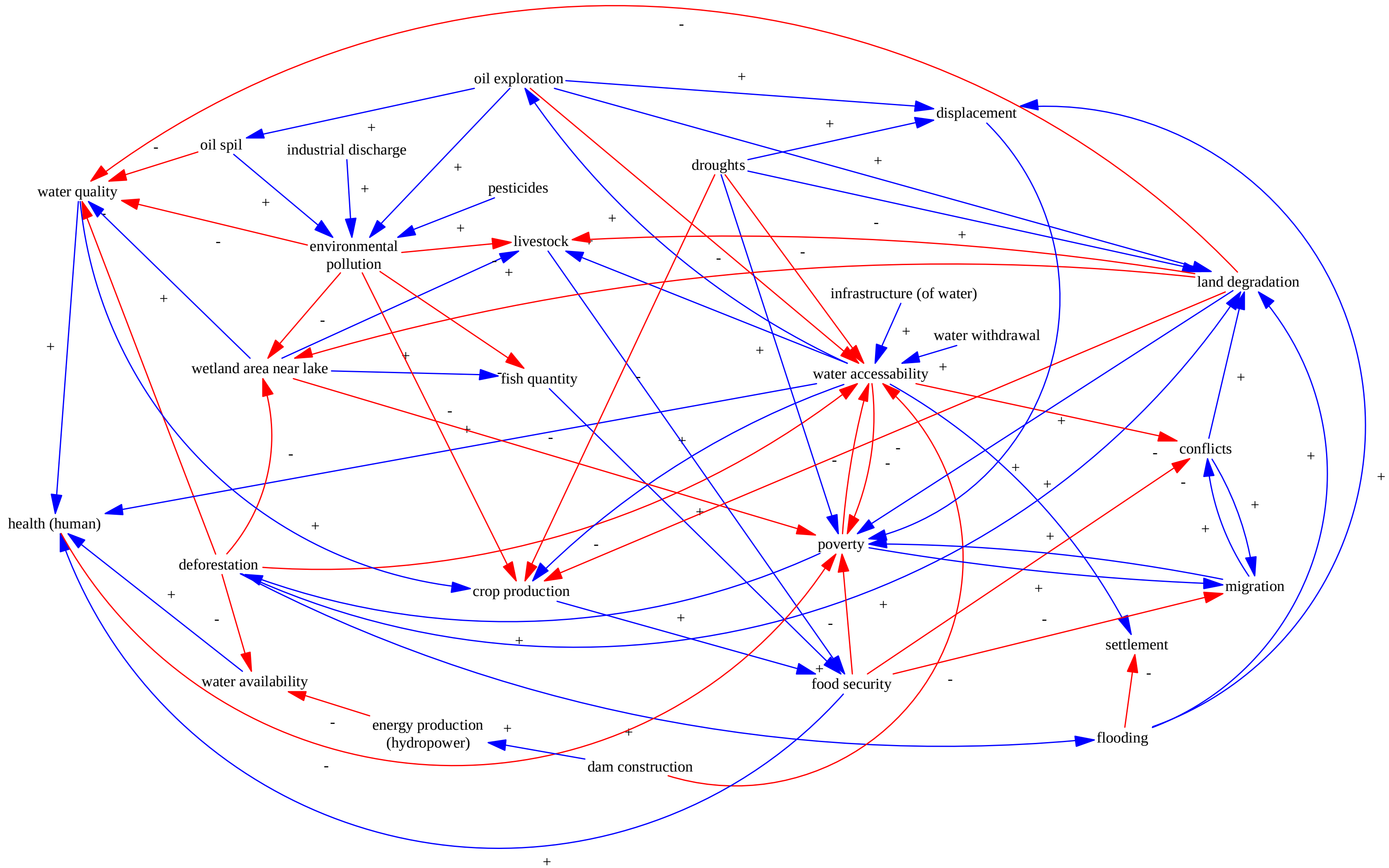

Figure 16: Individual CLD from participant Ken3

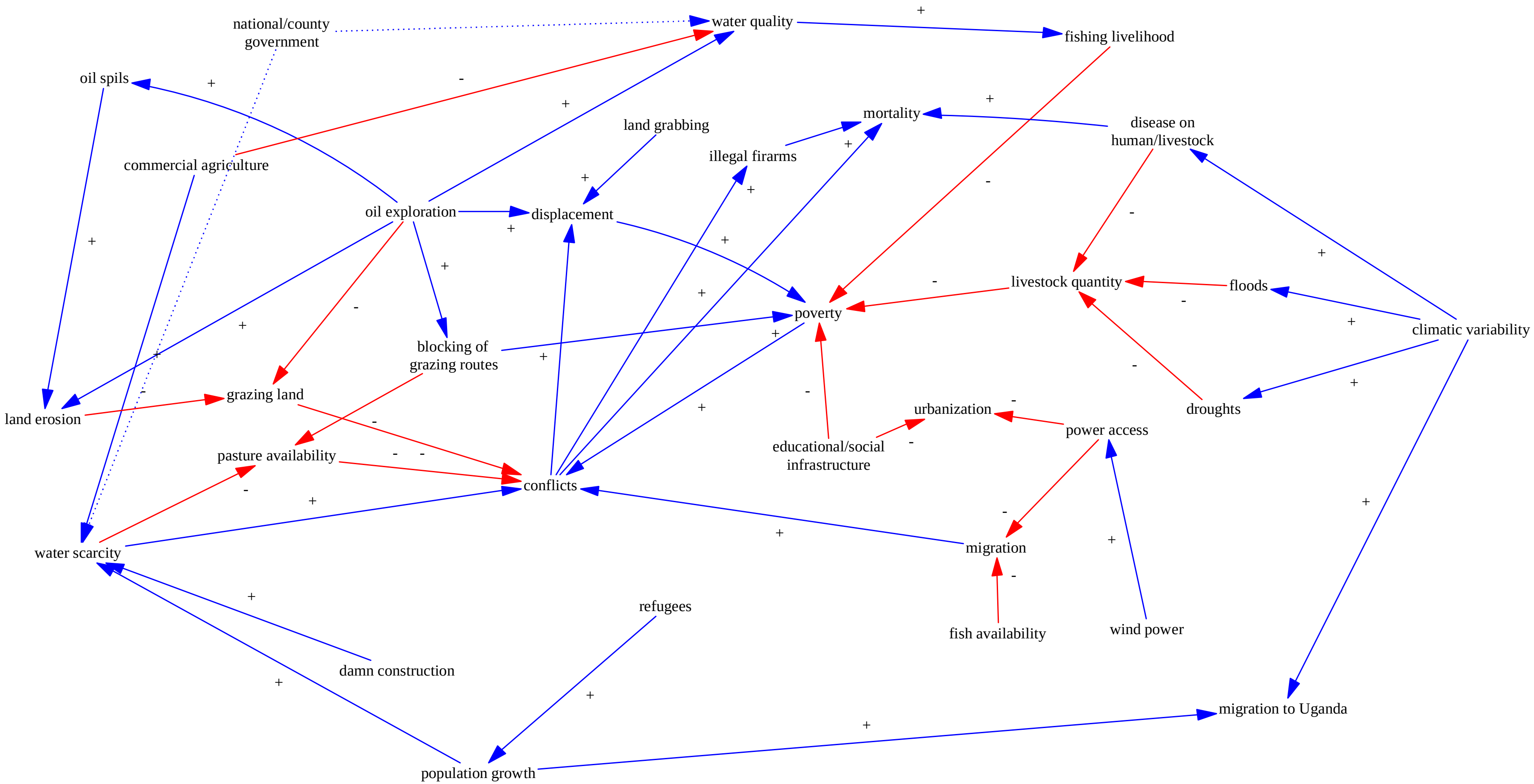

Figure 17: Individual CLD from participant Ken4

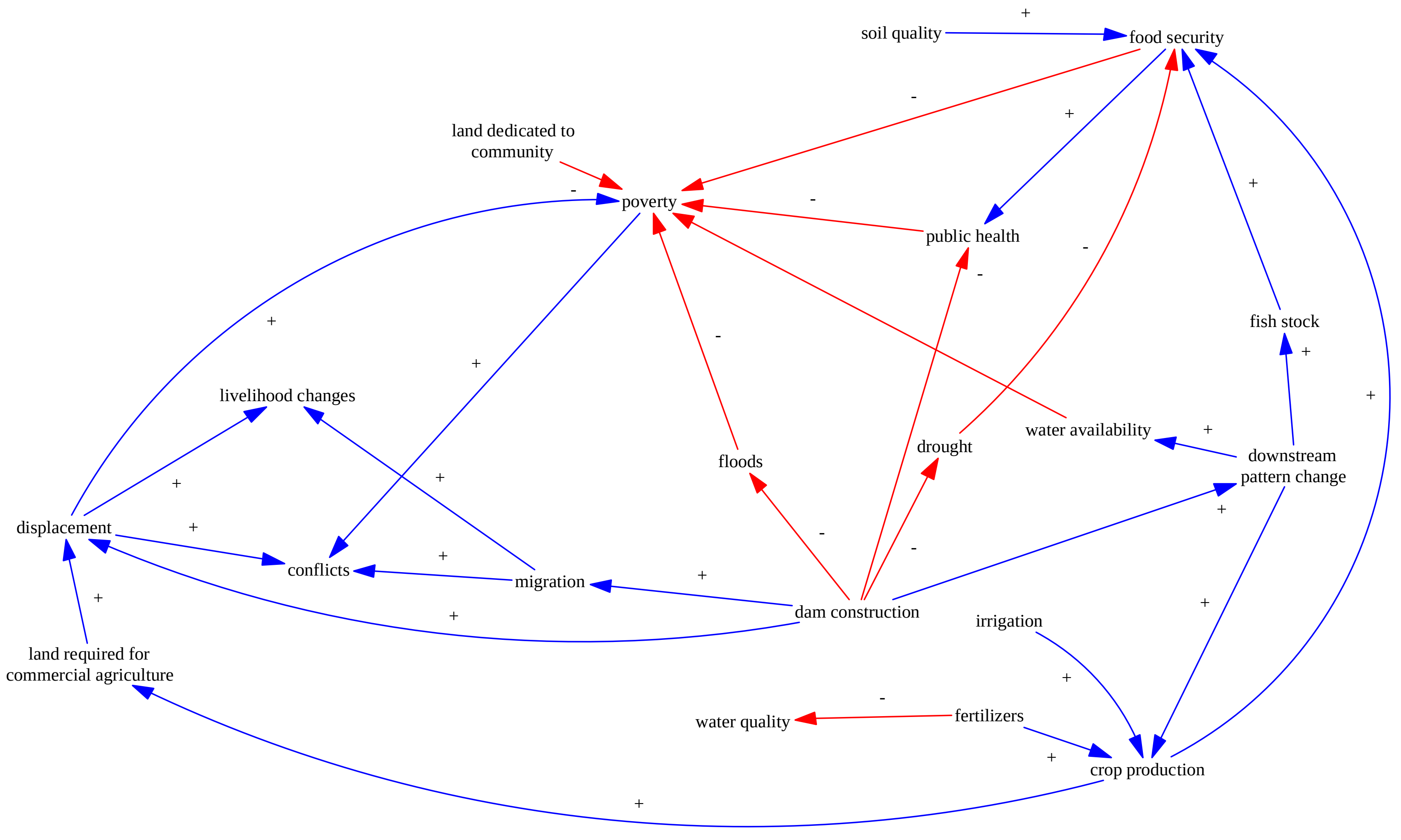

Figure 18: Individual CLD from participant ET1

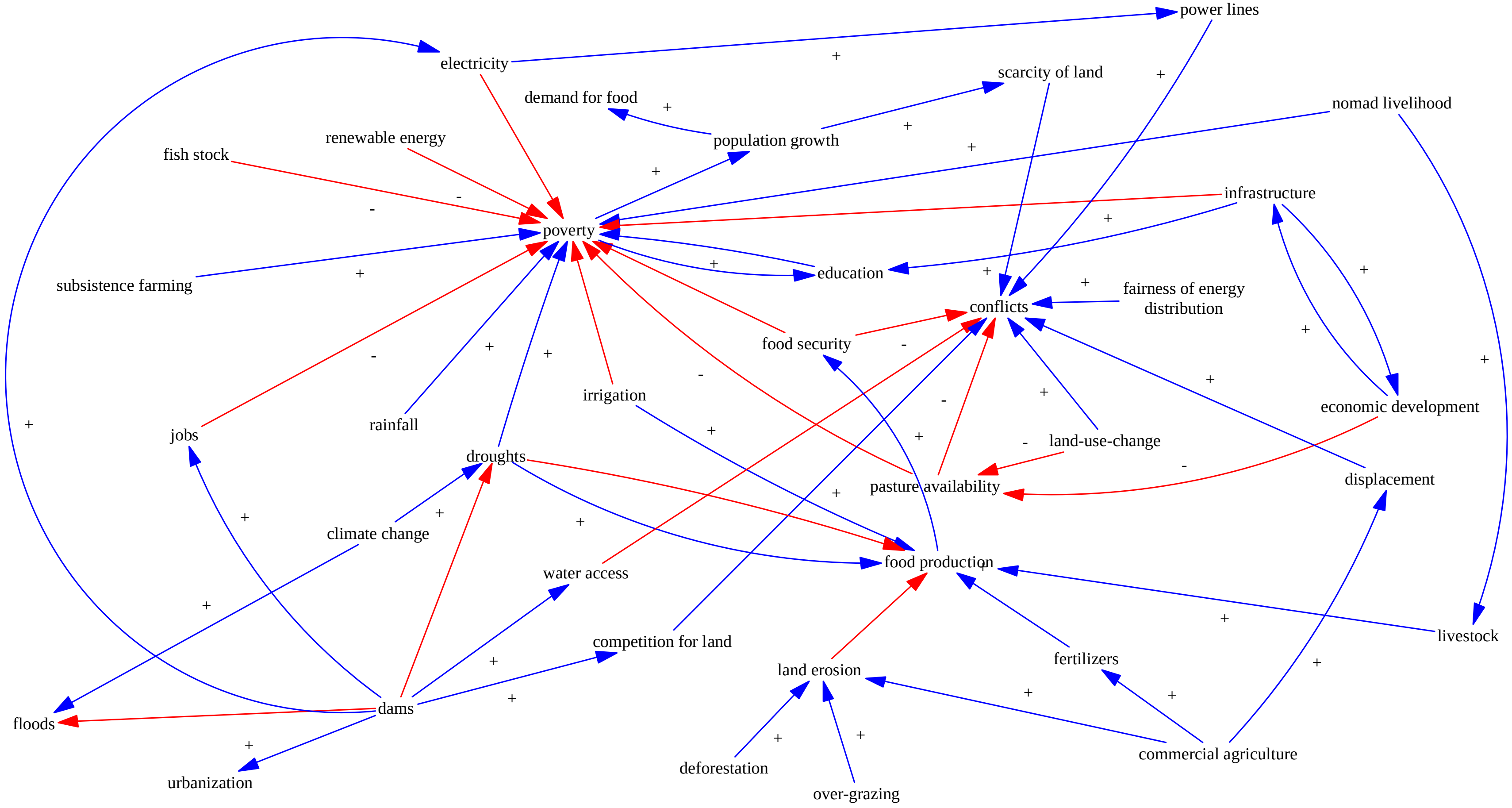

Figure 19: Individual CLD from participant ET2

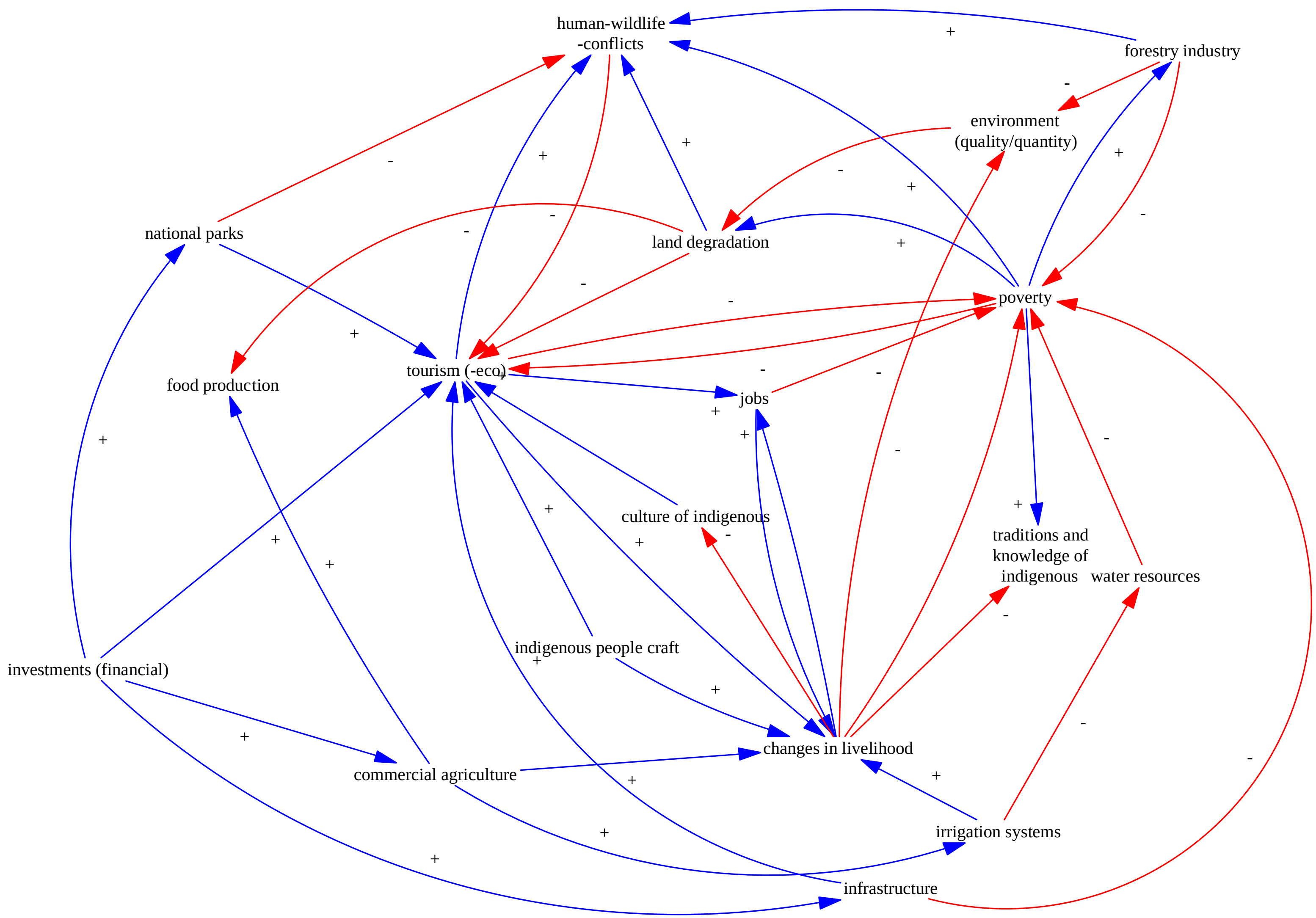

Figure 20: Individual CLD from participant ET3

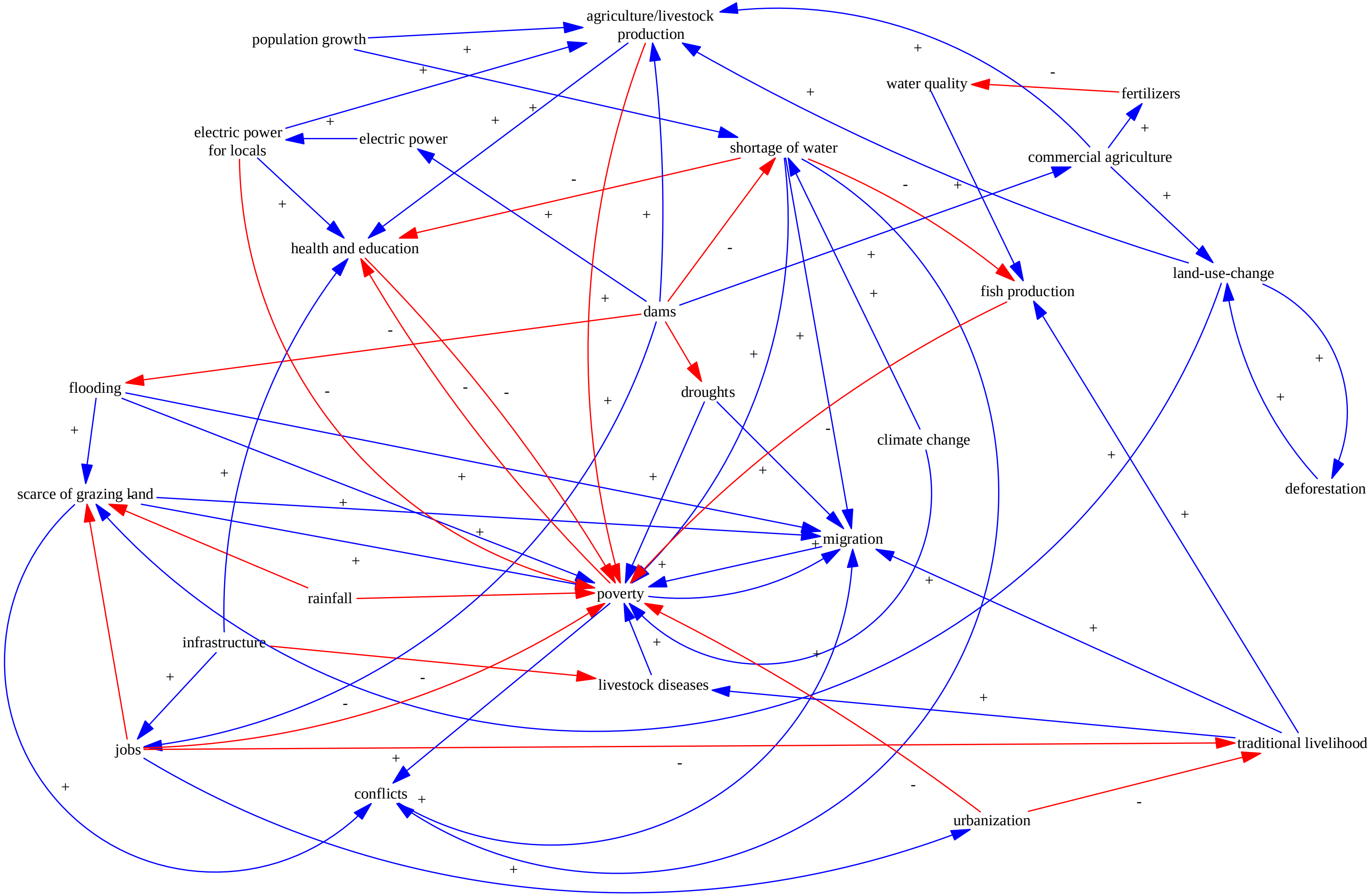

Figure 21: Individual CLD from participant ET4

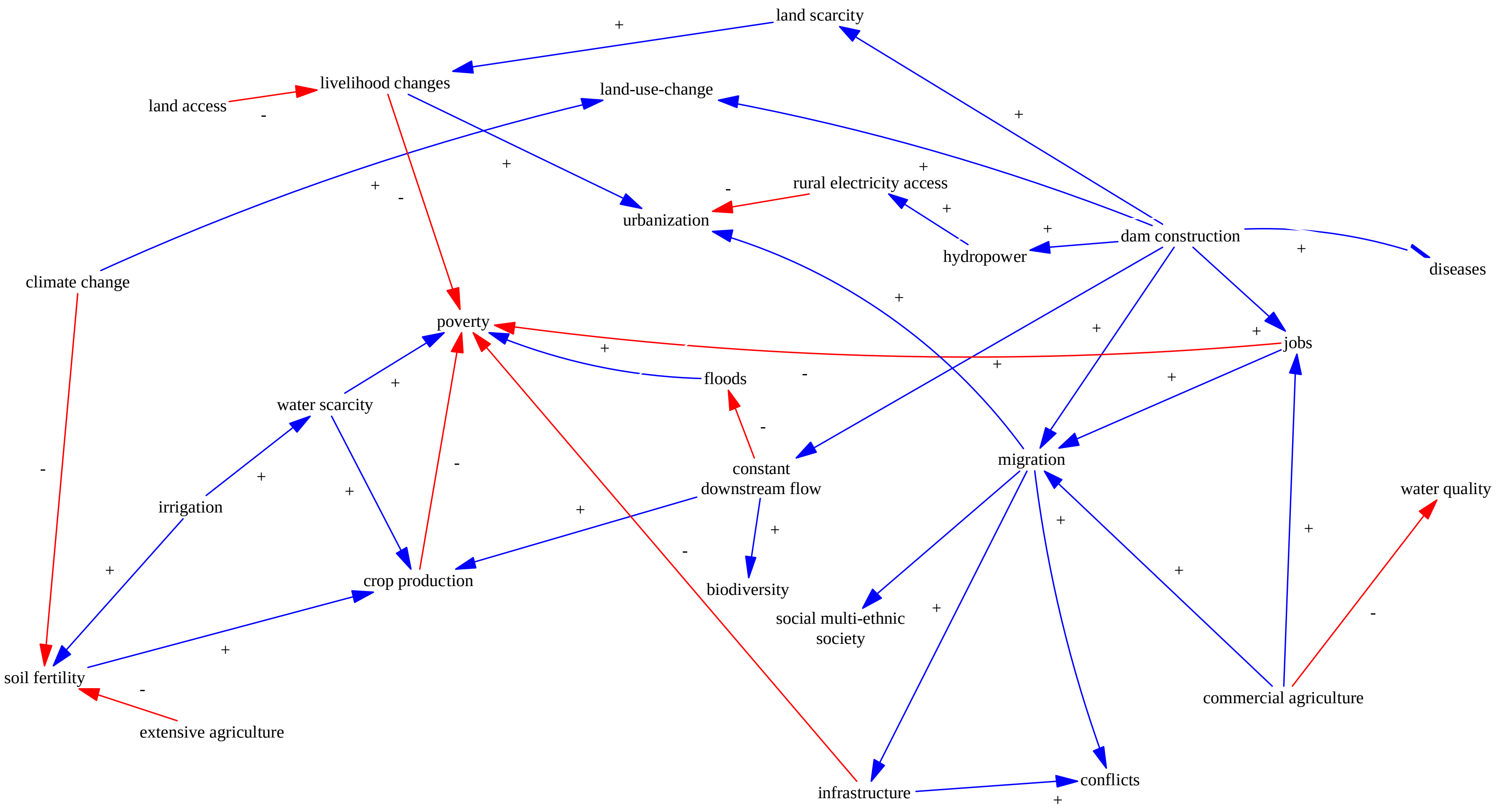

Figure 22: Individual CLD from participant ET5