It is worthy of mention that the residents of the Sahel Region have experienced a lot of hardships as a result of changes in rainfall patterns. In the past, the grave water deficiency during extensive droughts had destructive consequences for the population concerned, and partially caused irreversible ecological damages. The World Meteorological Organization (1985) recorded that in 1984, the drought in the Sahel affected about 250 million people from 22 countries. Several hundred thousand people died as a result of the droughts during the years 1972, 1973, 1977, and between 1982 and 1984. Furthermore, in Druyan's (1989) estimation, millions of people migrated to adjoining areas to save their lives. The large rainfall variability, therefore, makes West Africa a region with permanent climatic problems.

Due to the issues mentioned, there is the need for a sustainable management of the water resources of the Volta River Basin. The Global Change in the Hydrologic Cycle (GLOWA) Project therefore seeks to analyze the physical and socio-economic determinants of hydrological cycles, which will eventually lead to the development of a scientifically sound decision support system for the assessment, sustainable use and development of water resources in the Volta Basin of West Africa. The main scientific challenge of the project is therefore the integration of climatic, ecological and socio-economic factors with respect to the hydrological cycle.

It is envisaged that the decision support system will provide a comprehensive monitoring and simulation framework enabling decision makers to evaluate the impact of manageable (irrigation, primary water use, land use change, power generation, trans-boundary water allocation) and less manageable (climate change, rainfall variability, population pressure) factors on the social, economic, and biological productivity of water resources. Decision makers would thus be able to evaluate alternative development strategies and answer questions including the following:

- Is there a reduction in rainfall and an increase in rainfall variability? What would be the economic and ecological consequences of such a tendency?
- How can the limited available resources be reconciled with the present population increase and which water resource management strategy should be pursued?
- Which feedback loops between land use intensification and reduced rainfall are to be expected?

- What are the returns in terms of productivity and downstream availability of water resources yielded by large-scale irrigation schemes along major rivers or hydraulic development of small valleys in the upper reaches?
- What are the ecological and socio-economic consequences of an increased hydropower production (helping industries around Accra) and/or an improved agricultural productivity through irrigation in the north (reducing rural poverty)?
- What would be the impact of upstream dam building in Burkina Faso on the Volta River? Can win-win management strategies be developed which satisfy both countries?

The decision support system will take the form of a set of models, which can readily interchange information with the correct scale and format, and a shell within which the models can be used. The model will be dynamic, meaning the relations between variables and the rates of change may vary over time and space. As such, the model would do more than extrapolate present trends, by also capturing the functional relationships between different variables.

Integration of climatic, ecological and socio-economic factors and correlations with respect to the hydrologic cycle is the main scientific challenge of the project. The decision support system depends vitally on the input from many different scientific disciplines and the project is interdisciplinary in nature. The challenge for any interdisciplinary research project is on the one hand the development of a meaningful quantitative exchange of information, and on the other hand a synthesis of the different findings, which goes beyond a mere description of the links between social, economic, agronomic, hydrological and meteorological processes.

The means by which the quantitative exchange of information is pursued in the project is a set of dynamic models which capture all first order linkages between relevant processes in atmosphere, soil and water. In fact, it is the main scientific ambition to let the boundaries of the models coincide with physical boundaries of the Volta River watershed and not to depend on ad hoc assumptions about population growth, land use change, rainfall variability or hydropower demand. All models will be embedded in one shell which defines common interfaces and access to information pooled in a common database. With the exception of the interfaces, the models are independent enough to be developed, calibrated, verified and tested individually.

The dynamics in the project are addressed by dividing the research activities over three clusters: atmosphere, land use change, and water use and the definition of interfaces for exchanging information. The research activities within each cluster are undertaken by a small interdisciplinary team. It is expected that by concentrating the information exchange between disciplines in small groups, scientific problems between these disciplines will be addressed and solved at the on-set. Final project integration will take place by connecting the clusters through the well-defined, simply structured interfaces.

Each of the three clusters treats one important water redistribution complex, but between the clusters, the levels of manageability differ. The behavior of the atmosphere can not be managed although it is directly affected by macro-developments world-wide, which are treated as given externalities. Land cover and use, soil surface and vegetation, are managed but usually with the objective to obtain a crop and not with the objective to interfere in the hydrologic cycle. The application of management tools is restricted. Irrigation development, hydro-power dams and groundwater withdrawal are, however, the direct outcome of human intervention in the natural flow of water. Subsequently, the role of the social sciences increases from almost nil in the atmosphere cluster, to supportive in the land use cluster, and to dominant in the water use cluster.

The main variables which are modeled over space and time are:

1.Precipitation

2.Actual evapotranspiration

3. Agricultural production

4. Land use and land cover

5. Population dynamics (including growth and urbanization)

6. River flow

7. Water use

8. Hydro energy

9. Health

10. Technological development and

11. Institutional development

Variables 1 through 8 are endogenous variables, which will be modeled within the project. They are a function of other endogenous variables, and give dynamic feedback. Variables 9 through 11 are exogenous, with 9 being an output variable and 10 and 11 input variables. It is also realized that the three exogenous variables should ideally be produced and treated as endogenous variables but present state of knowledge inhibits such treatment. Consideration of the exogenous variables is a direct result of the project and gives social meaning to the project as a whole. Each sub-project produces output needed either by other sub-projects as variables for further calculation or as a variable for the whole model. Figure 1.1 shows the general structure and correlations between the sub-projects with each arrow representing major information input.

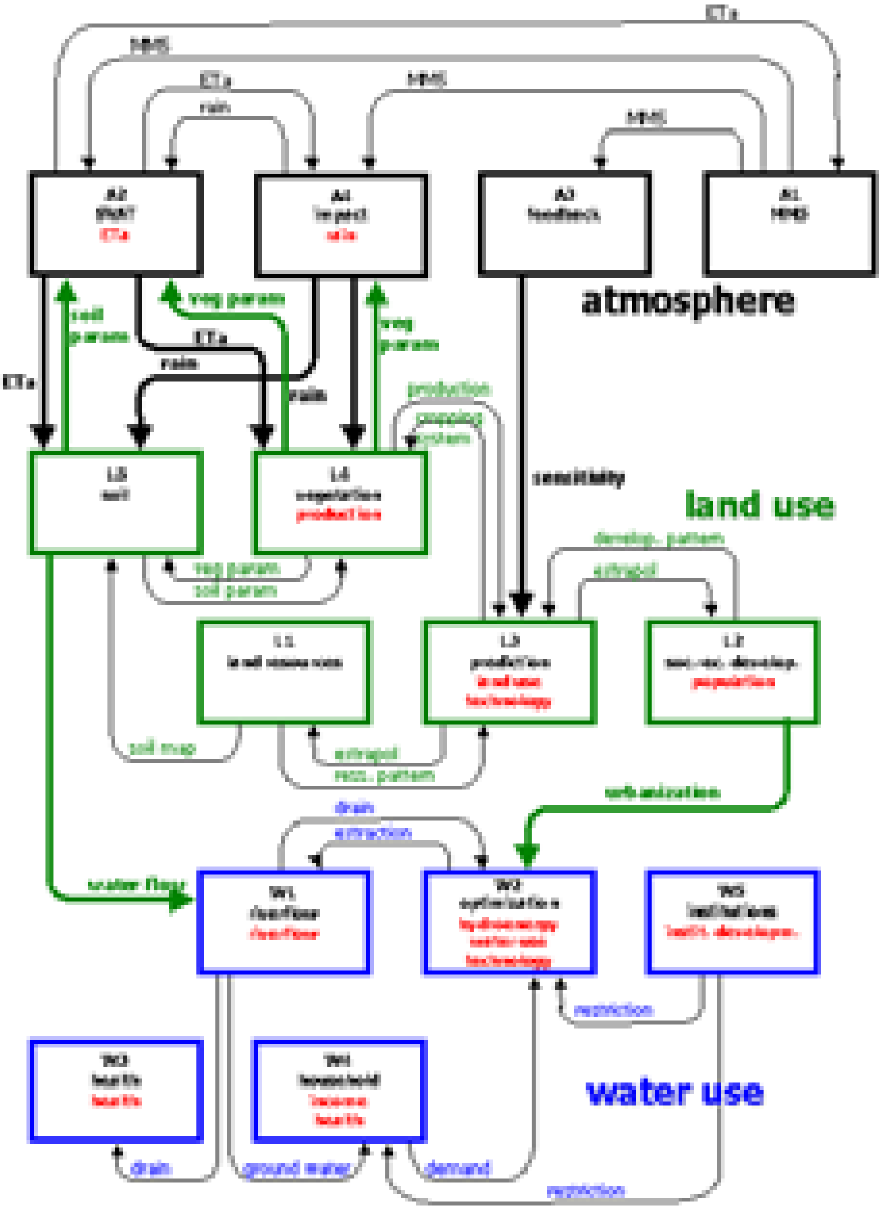

Figure 1.1: General structure of the GLOWA Volta Project

1.1.2 Population and land use/cover sub-project

Land is a very important asset and a means to sustain livelihood. It is the key and finite resource for most human activities including agriculture, industry, forestry, energy production, settlement, recreation, and water catchments and storage. Land is a fundamental factor of production, and through much of the course of human history, it has been tightly linked to economic growth. It is described as comprising biophysical