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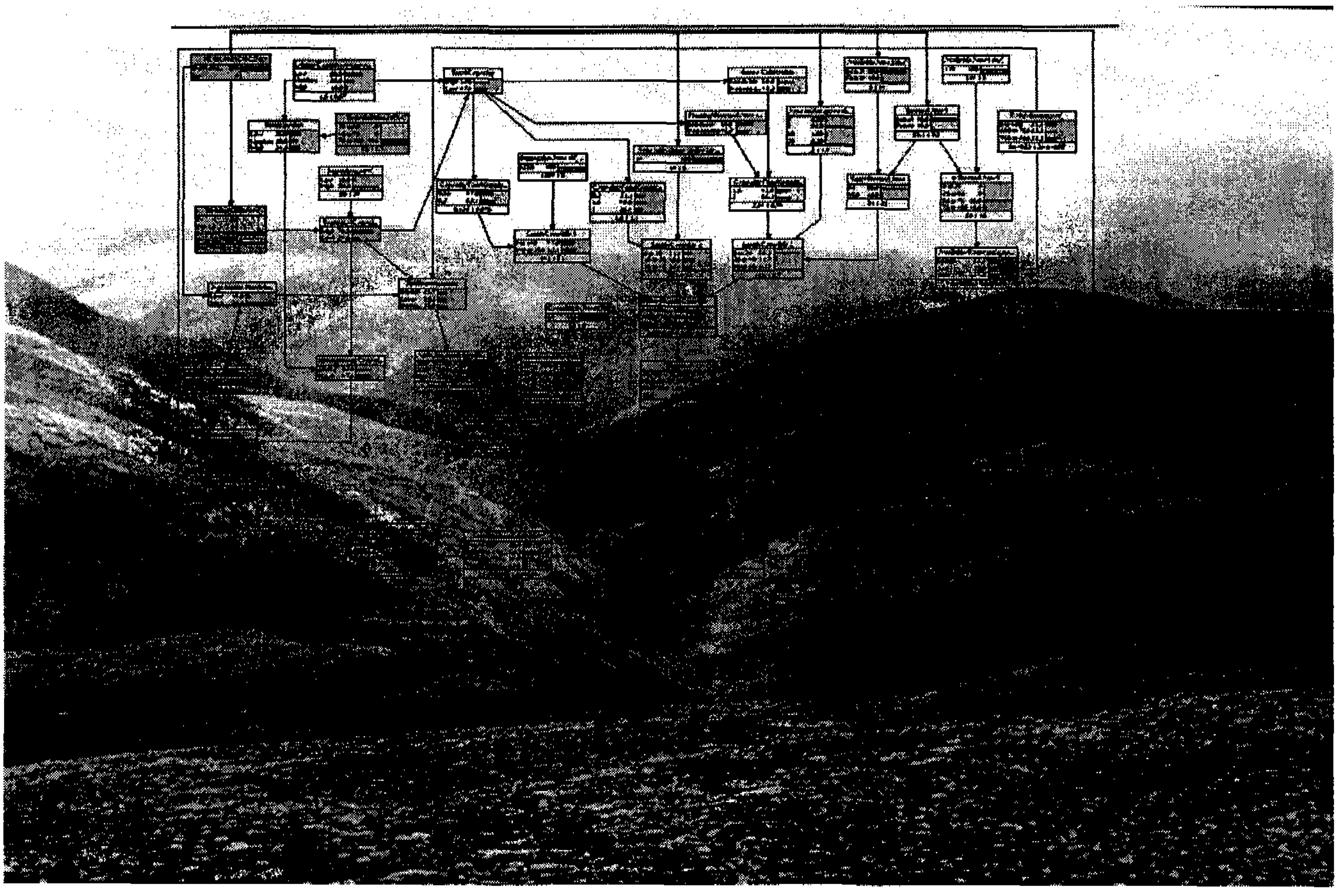

Use of Bayesian Networks as a DSS tool in Peru-Sierra Watershed Management

FINAL DRAFT

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Use of Bayesian Networks as a Decision Support System tool in the Peru – Sierra Watershed Management

By

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A thesis submitted to the programme of Water and Environmental Resources Management at the UNESO-IHE Institute for Water Education, Delft, The Netherlands, in partial fulfilment of the requirements for the degree of Master Science in Water Resources Management.

- FINAL DRAFT -

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"Manan unu kaqtinqa
manaya kawsay kanmanchu"

If there were no water
there would no be life

ABSTRACT

Watershed management, due to it works at low level, and strongly focused in integrated natural resources management, deals with different variables, from physical, biological, social, etc., making the analysis process difficult. To face that difficulty, managers start to implement the use of decision support system tools in integrated natural resources management. Bayesian Networks is one of those tools used with promises results. In Peru, watershed management is a new practice circumscribed at the mountain areas called Sierra, managers have also to face the same difficulties in the process analysis. In this research the performance of Bayesian Networks as decisions supports system tool in the Peru Sierra Watershed Management was test through the analysis of a small watershed in the sierra called Ayas.

The main objective of this research was to build a Bayesian Network with all the key factors of decision in Peru-Sierra Watershed Management, to find out how useful is a decision support tool like Bayesian Network in the decision making process.

Results indicate that the implementation of Bayesian Network as decision support system tool in Peru sierra watershed management it will not be possible until a monitoring system or system information is available. Therefore the analysis of watershed using Bayesian Networks provide a better understanding about watershed management in Peru, and will provide a framework to establish which are the indicators needed to implement an efficient and effective monitoring system.

Keywords: Watershed management; Decision support system; Bayesian Networks; Peru

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1 INTRODUCTION

1.1 Background

Watershed management in developing countries is a relatively new concept, focused on land management, erosion control, sedimentation, and flood control (Sheng 1999). In Peru, a developing country located in South America, watershed management is a new practice circumscribed at the mountains region called Sierra, focused on erosion control and poverty alleviation, under the hypothesis that a good Natural Resource Management is a pre-requisite for land productivity increases and consequently poverty is alleviated.

Watershed management, due to its works at low level, and strongly focused in integrated natural resources management, deals with different type of data, from physical, biological, social, etc., making the analysis process difficult.

To face the difficulties in process analysis and uncertainties involved in Integrated Natural resources management, land management, and agriculture management, many specialists have begun to use Decision Support Systems DSS, most of them found Bayesian Networks as a promising tool to cope with those difficulties.

Taking these considerations into account, the study will investigate the possibility of use Bayesian Networks as DSS tools in Peru Sierra watershed management

1.2 Objective

The main objective of this research is to build a Bayesian Network with all the key factors of decision in the Peru-Sierra Watershed Management, with the consequent understanding about the state of the art in community participation in this country. To find out how useful is the decision support tools like a Bayesian Network in the decision making process under a participatory approach in Peru – Sierra Watershed Management?

The study will focus only in the use of the tool, and how it can be used to evaluate a watershed system.

To achieve the objective proposed, a study area in Peru was chosen to analyze using the Bayesian Network. After carrying out a description of the watershed and identifying the principal activities and strategies of management, the Bayesian Network was built, to analyze the watershed management, and evaluate if the objectives are achieved.

1.3 Structure of the thesis

The Thesis consists of seven chapters:

Chapter 1. Starts of the thesis by giving a general introduction, and stating the objectives of the study.

Chapter 2. Contains the literature review about general concepts of water resources management, integrated water resources management and watershed management, and Water resources management and watershed management in Peru, and watersheds management, basic concepts about decision support system tools.

Chapter 3. Gives a general description of a big Project in watershed management, and the mean characteristics of the study area like: the physical, social, and economic issues. The objectives and strategies of the actual watershed management in Ayas, and the analysis of the available data.

Chapter 4. Gives a detailed description of the methodology to build the Bayesian Networks, scenarios and constraints in the use.

Chapter 5. Discuss the actual watershed management of the studied area using the model, focused in the evaluation of the fulfilment of the objectives of the watershed management.

Chapter 6. Gives the evaluation of the use of BN in watershed management

Chapter 7. Gives conclusions based on the study results and make recommendations for the use of BN, about watershed management, and for future research.

2 LITERATURE REVIEW

2.1 Introduction

Water resources management has been rapidly evolving based on experiences from around the world. While initially planners and managers used to take care only of big complex hydraulic systems, for the last 10 years a more multidisciplinary approach has been taken, and since 1990's, awareness of water scarcity and sustainability have changed thinking in water resources management. Concepts of integrated water resources management, participatory approaches, women's participation, water as an economic good, and equity, emerged and are now being practicing around the world. All of these relatively new concepts are still being redefined, questioned, and evaluated in day to day practice.

These "new" concepts of water resources management have been applied at local level in some developing countries to support the development of rural areas, in order to alleviate poverty. Some of those experiences show promising results, and now in many developing countries governments are implementing projects of water resources management and natural resources management at local level with the same aim: poverty alleviation, with a focus on trying to upscale the success. Peru is one of the developing countries that has been implementing this kind of Project at local level in more than 100 watersheds, where poverty is a common characteristic.

Monitoring and planning of those kind projects require a framework to facilitate the process, beside helping in decision-making process, and evaluating the management at local level. This is not only for the benefit of the process, but also more importantly to evaluate and learn about the new experiences, getting a better background for the upscale.

The present literature review has the purpose of conceptualising a better framework for the local level management. For that purpose, firstly a review of the basic concepts of water resources management, integrated water resources management (IWRM), and natural resources management is presented, highlighting the differences between activities in watersheds and basins. This is done to identify the main activities involved at those different scales. Also, the state of the art in water resources management and watershed management in Peru is presented in order to establish the key activities involved in the local level watershed management projects reported in this study. These include: alleviating poverty, identifying what are the priorities in the management at local level, showing how concepts of natural resources management are tackled, and identifying a framework for decision making under participatory approach.

Secondly in order to find a suitable framework for local level watershed management with a participatory approach, and knowing that decision support systems can be helpful, a review of the general concepts of decision support systems is presented. This is done with the aim of conceptualising a framework in decision-making and water resources management. A review of the concepts about Bayesian Networks and their application in water resources management is presented as Bayesian Networks provide a promising basis for a Decision Support Systems (DSS) that could cope with the wide range of uncertainty found in watershed management.

Finally the conclusions about those topics are presented. Indicating which kind of DSS tool looks like the most suitable for watershed management.

2.2 Concepts about watershed, water resources management, integrated water resources management (IWRM), and natural resources management.

Specialists involved in water resources management are familiar with terms like water resources management; integrated water resources management; and watershed management. Terms that are found in the titles of many conferences, workshops, publications, etc. However they remain new and often poorly defined concepts, and for a better understanding and in order to define the main difference among them, a review of these and other relevant concepts are presented.

2.2.1 Basic Concepts

Lets us first define what is a watershed.

The Natural Resource Institute, NRI (2002) states that watershed is the area of land that catches rainfall or snow and drains through a river system into a marsh, lake or the sea. This is the fundamental geographical planning unit for water and land resources, most used by planners and managers.

However scale is not mentioned in the definition, and many different terms related to watershed according to the size of the area, interest exists in distinguishing the small watersheds of the large by means of a different denomination for each one as Moriarty (2002b) states:

- When the area is around 10^3 to 10^4 $(km)^2$, then we refer to a river basin, catchment, or watershed.
- When the area is around 10^2 $(km)^2$, then we refer to a catchment, watershed, or sub-catchment.
- When the area is around 10^1 $(km)^2$, then we refer to watershed, micro-catchment, or micro-watershed, because of the small size the area is express usually in hectares.

There are many and good reasons to differentiate the large watershed of the small, many specialists agree in that, but not agreement with respect to the denominations exists.
In order to avoiding confusions, in this document the respective definitions will be established to distinguish the watershed by their size, as follows:

Basin
Is the area of land around 10^3 to 10^4 $(km)^2$ that catches rainfall or snow and drains through a river system into a marsh, lake or the sea.

Catchment
Is the area of land around 10^2 $(km)^2$ that catches rainfall or snow and drains through a river system into a marsh, lake or river.

Watershed
Is the area of land around 10 $(km)^2$ or 10,000 hectares that catches rainfall or snow and usually drains through a stream system into a river or small lake.

The management of water resources in general will not be the same at a basin level or at watershed level. This is because in the first one it is more common to find big hydraulic structures like reservoirs or hydroelectric systems, that are rare in watersheds. Equally quite different apart from the institutional and legal frameworks are found at the different scales. It is expected that the activities involved in water resources management be different according to the scale.

But what does water resources management mean, and which are the involved activities?

Following the main concepts related with water resources management as well the activities involved are presented.

Water Resources Management (WRM)

Water Resources Management (WRM) is defined as the whole set of technical, institutional, managerial, legal and operational activities required to plan, operate and manage water resources for sustainable use (Savenije, 2001).

Integrated Water Resources Management (IWRM)

Integrated water resources management (IWRM) is defined as the management of water resources described taking account of all natural aspects of the water resources, all sectoral interests and stakeholders, the spatial variation of resources and demands, relevant policy frameworks (national objectives and constraints) at all institutional levels (Savenije, 2001).

A more general definition is the one states by The Global Water Partnership GWP (2000): "IWRM is a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems."

For the purpose of this document when IWRM is mentioned, reference is made at the concept stated by Savenije (2001) assuming that all the natural aspects of water are related with land, and vital ecosystems.

The main difference between the concepts of WRM and IWRM, is the consideration of related resources with water, with a more broad coverage at all institutional levels and interests in the last one.

Integrated Natural Resources Management (INRM)

Integrated Natural Resources Management INRM, could be defined as the responsible and broad-based management of land, water, forest, and biological resources base including genes-needed to sustain agricultural productivity and avert degradation of potential productivity (INRM, 2002).

Nowadays increasing numbers of national plans and policies are considering the concepts of WRM, IWRM and INRM. From the experiences of their application it is important to highlight:

- IWRM usually works at basin level, focused in efficient allocation of water, and engineering led because of the hydraulic infrastructure hosted (Moriarty, 2002b).

- INRM is also being promoted with community groups and, in some cases, even with individual farmers through community-based natural resource management of common-property, open-access, and privately owned resources in watersheds, typically only in the range of 50,000 to 500,000 hectares. Social boundaries prevail, and many so called "watershed development" projects are being undertaken at this scale in developing countries (Lovell et al, 2002).

Then the concept of Watershed Management emerges.

Watershed Management

Watershed Management can be defined as the INRM applied at watershed level. In the fact that Watershed Management works focused more on the natural resources and participation, considering improvement of the environmental protection (Rockström, 2002) and maximising the local potential of green and blue water at watershed level (Moriarty, 2002b).

Then the main differences between the concepts of IWRM and Watershed Management are the scale and the focus of activities, although both frequently claim to work at multiple scales and involve stakeholders, in practice integrated water resources management tends to involve low-level stakeholders in a purely consultative role, and watershed management tends to focus on the lowest level and often bypasses higher ones (Moriarty, 2002b).

2.2.2 Concepts related to watershed management and participatory approach

Let's focus now on the concepts related to watershed management.

First watershed management is focussed at the watershed level and primarily on INRM, as it mentioned before.
Secondly, one important approach of the watershed management is to look for a full participation. But what is involved in participation at watershed level?

Watershed management with participation implies the full involvement of local populations in the identification of priority problems and potential solutions with teams of scientists, planners, and development specialists (Rhoades, 1998).

In the whole world watershed management with a participatory approach has been applied only since 1992, and as results evidences of success or failure at this point is almost entirely anecdotal (Rhoades, 1998).

One of the cases that shows success is the Indo – German watershed development program, in which watershed rehabilitation in semi-arid India not only reverses environmental degradation: largely through improved re-charge of groundwater, it permits a quantum shift in sustainable agricultural productivity in the lower slopes of the watersheds (Farrington et al, 1997).

Advantages of a Participatory Approach

From the experiences in the Indo – German case, which works in small watersheds of approximately 1000 hectares, the improvements as a result of the involvement of local people in watershed programs at community level can be remarkable, and include:

- Economic benefits: increases in land value, enterprise development and demand for labor. Substantial increases in crop and livestock yields (on average cereal yields doubled, with no additional use of external inputs);
- Social benefits: greater self-confidence and a sense of cohesion in communities, fewer conflicts over resources, reduced out-migration, and a new rapport between local people and external professionals; and
- Environmental benefits: recharge of aquifers, reduced soil erosion increased number of trees, reduced salinity, reduced use of fertilizers and pesticides, and the return of birds and other wildlife (Pretty et al, 1995).

Risks of Participatory Approach

Rhoades (1998) makes thorough analysis of participatory approaches, categorising the Conceptual and Operational risk, from that analysis the relevant facts are:

Conceptual

- Scale Problem. Physical scales are confused with human organisational scales and vice versa.
- Participatory Fetish. Rhoades express it in this terms: "Rather than treating local people with respect and as colleagues, participatory methods sometimes treat them more like school children by playing titillating games, drawing exercises, and other fly-by-night remedies".
- Participation is not synonymous with social analysis. Serious social and economic questions about watershed dynamic require as much care in research design as in the biological science.
- There are not enough available publications that evaluate success and failures of lessons.

Operational

- Great expectations. When a project is based in participatory approach, it means that the stakeholders will talk about all the problems, not only about the main objective of the Project, this talk then gets confused with what can be realistically accomplished in the project's time frame and budget.
- Participatory Commons. "When projects budgets are democratically open and competitively available, each stakeholder groups entrenches in terms of its own short-run goals, instead of opting for what is best for the whole group".
- Duplicating Management Structures. There is tendency to create artificial, externally conceived committees/groups through which the watershed project managers and workers can operate. It is better to use existing in vitro user-based institutions rather than setting up new organisations or committee that are likely to be more successful, but this option is rarely selected.
- Stakeholder Complexity and Competition. As the number of stakeholders increase, the likelihood of conflict increases.

Even given the benefits gained with the participation, it is important to realize that the activities undertaken in order to get the participation of the communities carry a financial cost (Cain, 2001), or as Morrison (2002) argues, while stakeholder involvement or participation can be considered a necessity for effective water management, it can also be considered a luxury because:

- It is time consuming (time is money).
- Unpredictable nature of the process
- The need for leadership/political will
- Iterative changes are incomplete or maybe too slow
- There is lack of analytical proof that stakeholder groups work

Uncertainties in Watershed Management

Not matter the local-scale of work, uncertainty exist in almost all the scenarios planners have to deal in the process of watershed management. As Savenije (2001) states for Water Resources Management, similarly happen in watershed management.

- Natural Scenarios: occurrences of droughts, floods disaster, uncertainty in forecast.
- Financial and Economic: variation in prices of agricultural products, livestock products and agricultural inputs, variations in the exchange ratios, or inflation.
- Socio-Economic: population growth, level of consumption, unemployment rates, willingness to pay, mentality.

- Political Scenarios: changes in government, changes in Institutions, changes in political system, outbreak of wars, policy changes.

All these are source of uncertainty; ones could be more relevant than others in a specific watershed, an other related to the Nature are always uncertain, even the watershed has a good system of forecast, or good monitoring and collecting data system.

Summarizing:

- IWRM takes place at basin level, focused more in the operation of big Hydraulic Infrastructures, with limited participation at low levels, focused more in water allocation.
- Watershed management takes place in small areas with a focus on integrated natural resource management and participatory approaches. While the benefits of participation are clear, it also carries risks, which must to be taken into account.
- Watershed management is being implemented in many developing countries, with few evidences of the results as the Indo – German case, Peru is another developing country where a big Project that includes more than 125 watersheds has been carried out by the Government since 1997.

2.2.3 Water Resources Management and Watershed Management in Peru

General Information

Peru is a developing country located in South America, 23 million people live in 1.3 million $(km)^2$. Because of the Cordillera range of the Andes, the country is divided into three major geographical regions: the Coast, the Highland, and the Jungle.

The Coast covers 10% of the total area of the country. It is an arid strip of variable width. The annual average rainfall is below 150 mm in the central and southern belt; in the extreme north the averages reaches 400 mm annually. The low rainfall of the coast region permits agriculture only under irrigation.

The Highland, called the Sierra, covers 30% of the country's total area. Rains in the Highland region have an annual mean of 300 mm in the southern zone, and 900 mm in the Northern zone. In this region, agriculture is principally dry land farming under complementary irrigation. The area is characterised by a combination of valley bottoms (generally intensively cropped, minor soil management problems) and steep lands (extensive, severely eroded and poorly managed rainfed cropping areas).

The Jungle region runs from 2000 m above sea level it covers 60% of the total area of the country. The rainfall distribution in this region is better than in the other two, with an annual average of 2 400 mm.

With the exception of the Jungle area, Peru has scarce water resources under conditions of extreme aridity.

The Institution in charge of the Administration of water is the Ministry of Agriculture.
Since 1969, the legal framework of Water resources management in Peru is based on the "General Water Law" (Ley General de Aguas). This law was announced under Military Government, and has a strong role for the State which retains most of the control. New legislation announced in the past years aims to rule some omissions in the original Law, but the Law and new legislation actually make the law system contradictory (Jouravlev, 2001).

Watershed Management in Peru

The Ministry of Agriculture of Peru, through **PRONAMACHCS (national program of watershed management and soil conservation)** has been working in watersheds located in the Sierra region since 1981. At the beginning, PRONAMACHCS carried out principally activities of soil conservation, only later undertaking tasks related to watershed management, oriented to livestock and agriculture. Added to its objectives, agriculture production and natural resources management oriented to integral rural development, is working according the concepts of watershed management.

The work of PRONAMACHCS is restricted to the Sierra region because:

a) The area suffers from intensive erosion due to natural processes, bad agriculture and livestock practices.
b) Has high indexes of poverty; according to MINAG (2002) 72% of people from the Sierra are in a state of poverty. Most of these people belong to the indigenous ethnic groups whose main activity is agriculture. The indigenous people have the biggest indices of poverty and the indices of poor educational attainment and unemployment are also high.
c) The indigenous people called *campesinos* live in close attachment to their natural resources, they live principally from subsistence-oriented production, with the erosion problems, they get less land to cultivate, consequently less income, and becomes poorest than before.
d) From their previous experiences in natural resources management in the last 20 years, it has been proved that good natural resource management is a pre–requisite for land productivity increases and **consequently poverty alleviation** (World Bank, 1997).

Watershed Management Activities in the Sierra of Peru

Typical activities involved in watershed management aimed at good natural resource management in the Sierra as identified by World Bank (1997) are:

- Soil conservation infrastructure works: bench terraces, slow formation terraces, infiltration furrows. The objective of this activity is improving the quality of the soil to make it suitable for agriculture, preventing erosion and decreasing runoff.
- Small scale irrigation works: construction and maintenance of small reservoirs, diversion structures, lining or channel construction, improvement of weirs. The objective of this activity is expanding and improving crop production efficiency.
- Agricultural Inputs: provision of seeds, fertilisers, construction of seed and input storage rooms. The objective of this activity is expanding and improving crop production efficiency.
- Reforestation and agro-forestry activities: seedling production, tree nurseries, improved forest management. The objective of this activity is reducing erosion problems and protecting farms field, and also promoting the timber production.
- Strengthening rural communities: technical training, community organisation, increasing management capacity and enhancing women's participation. The objective of this activity is providing basic skills to communities in order to make them more autonomous so that in future they can manage the watershed by themselves. This will have impact in most of the other activities listed earlier.

It is expected that by implementing this activities in poor areas of the sierra, poverty has to be alleviated.

The Ministry of Agriculture has been carrying out a Project called: **Peru-Sierra Natural Resources Management and Poverty Alleviation** in order to reduce poverty in the Sierra region since 1997. The Project was implemented by **PRONAMACHCS**, and is being implemented in the seven poorest administrative departments of the sierra. The geographical unit for the planning and implementation is the watershed, all the project covers 125 watersheds with an average area of 10,000 ha per unit. The project's overall strategy consists of participatory community natural resource management and land use planning, focused in the activities mentioned before. The desired end state is one of the community is autonomous enough to manage the watershed themselves.

Uncertainties in Watershed Management in Peru - Sierra

As we mentioned before, the uncertainties are involve in any watershed, with more relevance in some scenarios than others, in the case of watershed in Peru, the uncertainties related to each scenario are:

- Natural Scenarios: occurrences of droughts, floods disaster, in the Sierra of Peru the dramatic changes in weather produce a frozen phenomenon, that damage the crops, variations in the raining season affect the rainfed agriculture production.
- Financial and Economic: variation in prices of agricultural products, livestock products and agricultural inputs, variations in the exchange ratios, or inflation, this is a big one in developing countries like Peru.
- Socio-Economic: population growth, migration is one of the more important in rural areas in Peru, level of consumption, mentality mainly when deals with indigenous population as campesinos in the Sierra of Peru.
- Political Scenarios: changes in government, changes in Institutions, changes in policies. In the last 3 years a change in the government affect the PRONAMACHCS activities, because it was uncertainty about the fusion of this Institution with other.

It is important to consider the fact that watersheds in the Sierra of Peru, because of the level of poverty and inaccessibility, either have incomplete information or do not have the information required for a comprehensive physical description. These facts add more uncertainty to the process of planning and decision making becomes very difficult because of the big uncertainty in the variables, and difficulty in establishing the relationship between the objectives and the related activities.
This turn results many times in overlaying activities difficult to understand. Because of this, it becomes more difficult to explain to the community and promote their participation.

Watershed Management and Participation in Peru

Some facts that can facilitate the participatory approach to watershed management and community organisation in Peru, include:

- Community Organisations in the sierra evolve around land ownership and cultural traditions.
- Women are responsible for sixty percent of agricultural activities.
- The Departments with higher number of indigenous population are also the ones with higher rates of participation because of their cultural tradition of free labour contributions (***minka***) (World Bank, 1996).

Minka, is a quechua language, that means working system based in previous agreement, used in the Incas time (Rostworoski, 1999).

To get a better understanding about the meaning of free labour contributions, let us review some historical facts. These activities: free labour contributions, has their roots in the administration of the Incas culture, for instance Cuzco the ancient capital had subdivisions, the subdivisions of this large city were communities that functioned as irrigation districts, organized the recruitment of group labour, and fulfilled their obligations to ritual maintenance of the state calendar. Today through out the Andes, large-scale communal work is always broken down into sections and assigned to local communal groups wherever communities control their communal lives. These local communities are ***ayllus***. This term includes a sense of kinship, of sharing common ancestors, and of originating from the same local water sources. The ***ayllu*** is a spiritual community that shares rituals and tradition. It is an economic unit that cultivates its own crops, raises its own herds and is fundamentally self-sufficient for its basic needs. It shares work obligations and redistributes a surplus among its constituent families according to an ideology of reciprocity (***ayni***). It also is a legal unit that owns its lands and waters (Sherbondy, 1998).

In communities with this history and custom, participation through unpaid labour is not a problem in fact it facilitate the approach of community participation.

Summary

- Watershed management in Peru is circumscribed at the sierra Region, focused in poverty alleviation, based in the hypothesis that good natural resources management not only mitigates the problems of soil erosion but also, most importantly, it will help alleviate poverty in a sustainable way through good natural resources management.
- The uncertainties founded in watershed management in Peru are related to the multidisciplinary aspects involved in the management, being the Political and Social-Economic Scenarios as relevant as the natural.
- The implementation of a Decision Support System tool that facilitates the watershed management process under uncertainty conditions and participatory approach will be necessary.

2.3 Decision Support Systems: Bayesian Networks

2.3.1 Key Concepts of Decision Support Systems

What is a DSS?

Power (2002) defines Decision Support Systems (DSS) as "a specific class of computerized information system that support decision-making activities. DSS are interactive computer-based systems intended to help decision maker use data, documents, knowledge and/or models to identify and solve problems and make decisions."

But as Johnson (1986) states DSS are not only for the use of decision makers, DSS also aid operators in making implementation and operational decisions, and understanding probable system performance.

DSS are helpful as tools for decision-making and operation, and can additionally serve as vehicles for communication, training, forecasting and experimentation (Welp, 2000).

Categories of DSSs

Specialists make different categorizations of DSS, some of them are very complicated and others simple. In order to have a general idea about it, the following broad categorization according to Bhargava and Power stated by Bakker-Dhaliwal et al (2001) is presented:

1. Communications-driven DSS emphasizes communications, collaboration, and shared decision-making support. Examples are simple bulletin boards, threaded e-mails, audio conferencing, document sharing, electronic mail, ...etc.
2. Data-driven DSS emphasizes access to and manipulation of time-series data from an internal or external database source. Users can access relevant data by simple query and retrieval tools for further synthesis and analysis: an example is weather-related databases.
3. Document-driven DSS integrates a variety of storage and processing technologies to provide users document retrieval and analysis: this may sometimes be found in libraries.
4. Knowledge-driven DSS is an expert or rule based system where facts, rules, information, and procedures are organized into schemes that allow for more informed and effective decision-making. This is also sometimes referred to as the "expert" type of DSS.
5. Model-driven DSS emphasizes access to and manipulation of a model, for example, statistical, financial, optimization, simulation, and deterministic, stochastic, or logic modelling. Model driven DSS generally requires input data from the end-user to aid in analyzing a situation.

From those different categories, knowledge-driven DSS looks like one of the most useful for decision – making, then we can expect it will be useful also in water resources management. With the attention focused in the definition of the Knowledge-driven DSS, the definitions says that it is an expert or rule based system. What is an expert or ruled based system?

Jensen (1996) defines those terms as:

Rule Based systems.
The vision of this technology was that experts could be replaced by computer systems. The Rule Base systems consist of a knowledge base, and an inference system. The knowledge base is a set of production rules: if – then questions. The inference system combines rules and observations to come up with conclusions regarding the state of the world and likely actions. One of the major problems of this kind of system is how to treat uncertainty

Expert Systems or Normative Expert systems.
They are an alternative to rule based expert systems. Instead of modelling the expert, model the domain. Use classical probability calculus and decision theory. Instead of replacing the expert support him.

It is important mention that different DSSs can be used in the same watershed, each one with different role, and for different objective, in the different stages of the management process.

Use of DSS in Water Resources

The use of DSSs in water resources dates back to 1970s, at that time models-driven DSSs focusing on basin wide resources management were the most used

Most of them are generalized DSS software of hydrology models like IRAS, RiverWare, TERRA, NELUP DSS, DESRT, and AQUATOOL. (Ito et al, 2001)

The advantages of those models

- They are flexible for application to different river basins.
- Models like those, created for simulation and optimization can help provide operational guidelines

Disadvantages:

- They are often not sufficient to accurately represent the site-specific features of river basins and the changing multiple objectives of the practical management scenarios because of the complex characteristics of catchments.
- Besides they have a weak performance in dealing with uncertainty conditions such as inflow to reservoirs (Ito et al, 2001).

At present, Knowledge-based DSSs are more common in the field of water resources management. Those kinds of DSSs as Arumugam and Mohan (1997) state, can aid in operational decisions, allowing the incorporation of heuristic, subjective, and judgmental knowledge into the solution process.

The advantage Knowledge-based DSSs is that they can help structure decision processes and support analysis of the consequences of possible decision choices by making data easily accessible and allowing "what – if" analyses (Cain, 2001).

How about Multi-criteria analysis?

Multi-Criteria Analysis is a decision-making tool developed for complex multi-criteria problems that include qualitative and/or quantitative aspects of the problem in the decision-making process (Mendoza, 1999). It refers to a set of techniques, which aim to obtain a ranking of alternative strategies, while the effects of these strategies can not be translated to a single measuring rod (for example monetary units), but are expressed in units which reflect as good as possible the nature of the criteria concerned (Heun, 2000). It is one of the tools more known and used in water resources management.

MCA is more suited to decisions where it is not important to understand the underlying workings of the system in detail (Cain, 2001). It will be difficult for the stakeholder to understand it, because parts of the multi-criteria evaluation methods may be technically too complex.

DSS in Watershed Management

Watershed managers view watersheds in a fully integrated social, economic, hydrologic, and ecological context, dealing with many uncertainties, and considering the implications of the participatory approach.

Hence, a decision support system (DSS) with a mathematical framework that allows the manager to test alternatives with respect to all these considerations, and allows interdisciplinary data capture and analysis is required.

Belief and decision networks can provide this framework, allowing simple, integrated methodology for the modelling of complex systems (Batchelor and Cain, 1999), and can deal with uncertainties.

Besides the graphical interface of Bayesian Networks, makes easy for the stakeholders understand the system and participate in the decision – making process.

In the other hand Simulation models are not by themselves suitable DSSs, but can be used to feed information (Westervelt, 2000).

2.3.2 Key Concepts and applications of Bayesian Networks

Key Concepts of Bayesian Networks

Bayesian Decision theory has its roots in the work of an 18th century cleric Rev. Bayes, however, its modern form traces to the work of Jhon Von Neumann, a mathematician and computer pioneer, in the 1940's; and J. Savage in the 1950's. In Savage's formulation, a decision problem has three elements: (1) Beliefs about the world; (2) a set of action alternatives; and (3) preferences over the possible outcomes of alternative actions. Bayesian decision theory excels in situation characterized by uncertainty and risk, situations where the available information is imprecise, incomplete, and even inconsistent, and in which outcomes can be uncertain and the decision maker's attitude towards them can vary widely (D'Ambrosio, 2003).

In recent years, a set of probabilistic, Bayesian-type approaches applicable or potentially applicable were used for decision analysis under high uncertainty. These techniques are known as belief networks, causal network, Bayesian Nets, qualitative Markov networks, influence diagrams, or constraint networks. They have spread quickly to many application areas, including fault diagnosis, reliability theory, medicine, and pattern recognition (Varis, 1998).

Here focus will made in one of the techniques, the Bayesian Networks or Belief Networks.

Bayesian Networks are defined as a graphical tool for building decision support systems to help make decisions under uncertain conditions, and to show uncertainty in a way that can be clearly understood (Cain, 2001).

Bayesian networks are composed of three elements:

- A set of nodes (management system variables), representing states of nature. The variables can either be discrete or continuous.
- A set of links (causal relationship between the nodes), and

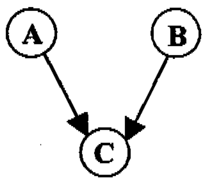
- A set of probabilities. One for each node, specifying the belief that a node will be in a particular state given the states of those nodes that affect directly. These are called conditional probability tables and can be used to express how the relationships between the nodes operate (Cain, 2001).

Bayesian Belief Networks

Bayesian Belief Networks are a powerful modelling tool that are based on the underlying premises of Bayes' rule a central axiom of probability theory.

BBNs allow a larger number of causal relationships between variables (called 'nodes') to be linked together in a network, into which observations (referred to as 'findings') may be entered. The effects of these observations on other elements of the graph are then modelled. Each node has a number of distinct 'states', with a probability associated with each one. States may be words, phrases, or numerical ranges.

Each node in a BBN is underlain by a "conditional probability table" which gives the probabilities associated with each of its possible states for all combinations of states of the nodes feeding into it ('parent' nodes). The diagram shows a causal diagram and conditional probability table for a node (C) with two parents (A, B).



A	B	C	
		True	False
True	False	0.8	0.2
False	True	0.2	0.8
True	True	0.5	0.5
False	False	0.5	0.5

In this example each of the nodes may have two states – true or false, and the table gives the probability for C to be in each of those states for all permutations and combinations of the states of its parent nodes. The sum of probabilities for each combination of states will always be one. The conditional probability table therefore states that, 'if A is true, and B false, there is an 80% probability that C is true'.

In its baseline state, a BBN reflects the spread of probabilities for all nodes, as soon as findings start to be entered into it the uncertainty associated with the entire network will start to diminish, and the range of possible states becomes constrained.
(Moriarty, 2000).

The probabilities representing the linkages, reflected in the Conditional Probability Tables, can be developed empirically or through expert judgement (Rieman et al, 2001), based on previous information. There are different source of information.

Sources of Information for Bayesian Networks

The information that feeds BN through the Conditional Probability Tables, could come from diverse sources, as Cain (2001) states:
- Empirical Data. Data collected by direct measurement.
- Participatory Input. Data collected through stakeholder elicitation.
- Models. Output from process-based models calibrated using data collected by direct measures.
- Expert Opinion. Academic 'expert' opinion based on theoretical calculation or best judgement.

The expert is not only the person with academic background, but could also be one of the stakeholders who's understanding of the system structure with people

Advantages of Bayesian Networks

As already it has been mentioned, the use of Bayesian Networks has diverse advantages that can be described as Batchelor and Cain (1999) mentioned as follow:

- Because of its graphical nature, promote formal discussion about the system structure among stakeholder from a wide variety of backgrounds and so encourages interdisciplinary discussion and participation.
- The relationships between variables from different context can be done in uncertain terms. It will help to understand in the system, the relationship between physical and socio-economic dynamics.
- The approach enables expert knowledge to be incorporated into the model on the same basis as more objectively derived data. Such features allow the creation of a model, which may contain mathematical relationships as well as subjective elements corresponding to the experience of the people who are, in many cases, an integral part of the system being modelled.
- Will facilitate the formal identification of the system variables and interactions.
- A distinct advantage of this approach is that Bayesian Networks do not have to incorporate the complete mechanistic detail of more process-based models (Rieman et al, 2001).
- It is relatively simple to adapt Bayesian Networks to new situations.

One fact about the use of Bayesian Network that is relevant mentioned is: ***"...Bns do not make decisions. They simply show the impact of any particular action on all factors linked to it, with all the attendant uncertainties; it is left to the planner or manager to make the final choice. But with the network the whole process of decision-making is made to be much more inclusive and transparent"*** **(Bromley 2002).**

Limitations of Bayesian networks

Despite these benefits the, BBNs have important limitations

- Uncertainty is explicit in the use of conditional probabilities. This uncertainty reflects the limitations of understanding and information but also means that important trends and differences can be obscured. Because much of the information represented in the networks is subjective, the outputs should be viewed only as relative trends among alternatives rather than absolute numbers or true probabilities (Rieman et al, 2001).
- Time consuming, because it requires stakeholder consultation and data collection and collation.
- Activities to collect subjective data involve an extra cost.(Cain, 2001).

As Rieman et al (2001) state, ***"all models are wrong, but some are useful, Box (1979)."*** Used appropriately the BBNs, it can provide insight into the potential effects and differences of management in a watershed.

Application of Bayesian Networks in Watershed and Natural Resources Management

Only few cases of application of Bayesian Networks in watershed management were found following, the most relevant aspects of each one are presented.

Case 1
"Evaluation of potential effects of federal land management alternatives on trends of salmonids and their habitats in the interior Columbia River basin" by Rieman et al (2001)

They developed a Bayesian Network that represented current understanding and available information with the key processes linking aquatic ecosystems and land management activities, according what they believe.

The lessons outstanding from the use of the Bayesian Network are:

- They believe their analysis provides a useful step for broad scale land management planning.
- Complex physical and biological interactions and management alternatives can be compartmentalized into simpler, more comprehensible components. By formalizing their understanding and assumptions, they provided a framework for exploring differences in the management alternatives that is quantifiable, spatially explicit, and flexible. Those assumptions can be challenged and revised, and they can be directly evaluated to determine whether results are robust.

Case 2
Application of belief networks to water management studies (application in Zimbabwe and Mauritius) by Batchelor, Ch. and Cain, J. (1999.)

From those experience they arrived to the following conclusions:
- Belief networks provide a powerful tool for simulating the interactions between physical, social and economic variables.
- Belief networks provide a mathematical framework that facilitates interdisciplinary data capture and analysis.
- A better understanding of the constraints on improved water management is obtained from this improved dialogue between researchers and stakeholder.

They suggest that the relationships between the nodes could be expanded to make better use of recorded data and stakeholder knowledge, but it is encouraging that the networks produce beliefs that are consistent with field observation. This will be a sort of calibration of the model.

In these two cases, the expectations in the use of the Bayesian Network were covered. In both cases the Bayesian Network provide the framework for a better understanding of the system, allowing the interaction of physical and non-physical variables.

2.4 Conclusions

After this broad literature review the following conclusions can be drawn:

- Integrated water resources management IWRM, is the management of water resources taking account all natural aspects (land and vital ecosystems), all sectoral interests and stakeholders, the spatial variations of resources and demand, relevant policy frameworks at all institutional levels; works at basin level, focused in efficient allocation of water, and engineer lead. It involves low-level stakeholders in a consultative role.
- Integrated Natural Resources Management INRM, is the broad-based management of the land, water, forest and biological resources base to sustain agricultural productive and improving agricultural productivity and improved agricultural productivity; involves participation at lowest level often bypassing higher levels.
- Watershed Management is the Integrated Natural Resources Management at watershed level, aiming to arrive at better understanding of the system (natural, physical, political, social, etc) as a unity, focused in participatory approach.
- There is a lack of analytical proof about success or failure cases in watershed management under participatory approach, then Participatory Approach has to be applied, taking account the benefits, risks, and financial costs implied.
- The process of Watershed Management has to deal with many uncertainties, as many different disciplines are involved.
- Watershed Management in Peru, as is defined in this document, it is a new practice circumscribed at the Sierra region.
- Watershed Management in Sierra of Peru is focused in poverty alleviation, under the hypothesis that a good Natural Resource Management is a pre–requisite for land productivity increases and consequently poverty alleviation.
- Even it is carrying out a big Project in more than 125 watersheds in the Sierra region of Peru; there is not documented previous experience about watershed management under participatory approach.
- Uncertainty in watershed management in Peru is not related only to the natural conditions in the Sierra, the Political and socio-economic unstable conditions give high uncertainty.
- Decision Support System Tools, are only tools to help in decision-making, they are not going to take decision by themselves, only facilitate the process.
- Watershed management, due to it works at low level, and strongly focused in integrated natural resources management, it deals with different type of data, from physical, biological, social, etc., needs of DSS to facilitate the process.
- Bayesian Network or Beliefs Network are suitable as decision support system tool in watershed management under participatory approach, because it can work under uncertainty conditions, provide the mathematical framework needed for the interdisciplinary data capture and analysis, and its graphical presentation facilitate participation.

3 Description of the Studied Area

3.1 About Peru – Sierra Natural Resources Management and Poverty Alleviation Project

The Peruvian government is carrying out the Project called: **Peru-Sierra Natural Resources Management and Poverty Alleviation.** The Project is being implemented since 1997 by **PRONAMACHCS** (national program of watershed management and soil conservation) under the authority of the Ministry of Agriculture. Initially it was going to finish in June 2003, but has been extended and will finalize in March 2004. The project is financed by a loan from the World Bank as well as the government of Peru (World Bank, 2003).

The general project objective is to help alleviate the poverty of the rural Sierra people by promoting a productive and sustainable use of their natural resources in a participatory manner. Specific project objectives are to assist about 75,000 poor families in watersheds of the Sierra to: (i) manage their natural resources through sustainable soil conservation and reforestation; (ii) increase rural productivity through irrigation and improved agricultural practices; and (iii) strengthen their rural organizations so that they can become autonomous and sustainable entities.

The project has four components: (1) participative identification and formulation of rural investments in micro-catchments; (2) rural investments; (3) strengthening of rural community institutions; and (4) logistical support and training to the implementing agency: PRONAMACHCS.

The geographical unit for the planning and implementation is the watershed, and the project covers a total of more than 125 watersheds with an average area of 10,000 ha per unit. The project's overall strategy consists of participative community natural resource management and land use planning.

The watersheds selected under the project are situated in the very poor higher Sierra areas where possibilities for productive development without outside assistance are rather scarce. Project activities target these poor communities who have sufficient natural resources to increase their income level through enhanced natural resources management. The watersheds selected for the Project area shown in the following table.

Table 3. 1. Scope of Peru – Sierra Natural Resources Management and Poverty Alleviation Project.

Department	Poverty (%)[1]	N° of Watersheds	N° Campesino Communities	N° Benefited Families
Amazonas	74.5	21	107	2785
Ancash	61.1	23	161	4246
Apurímac	78.0	19	127	4344
Ayacucho	72.5	7	47	1010
Cajamarca	77.4	19	121	4597
Cusco	75.3	4	41	1532
Huancavelica	88.0	26	141	3181
Huánuco	78.9	43	216	6341
Junín	57.5	15	114	4115
TOTAL		**177**	**1075**	**32151**

[1]: Percentage from total department population
Source: PRONAMACHCS (2002) and INEI (2001).

PRONAMACHCS is an Institution that has being working in Peru – Sierra watersheds, since 1981 with the aim of soil erosion control and a further orientation to agriculture and rural development. Recently PRONAMACHCS added to its objectives, agriculture production and natural resources management oriented to integral rural development

3.2 Successful Cases in the Project

An evaluation of successful cases under the scope of the Project was done in July 2002. The evaluation was done in order to:

- Evaluate the economic and financial feasibility; and the organisational - environmental sustainability of the Project in 10 Campesinos Communities.
- Analyse the influential factors in the results of the Project and;
- Formulate recommendations in case of extension in the project.

The selection was made by a survey in the different agencies of PRONAMACHCS. The survey was asking to propose 10 names of Campesinos Communities that, according the following criteria could be considered as successful cases:

- There is a positive general perception of the beneficiaries, about the results of the Project intervention.
- The Campesino Community has executed the works planned without misfortunes and the results of the intervention are visible and subject to evaluation.
- A diversity of works (soil conservation, irrigation, forestry, etc) exists financed by the project, with an average of three years of use.
- The works and practices have really contributed to the increment of productive base of the Community.

According to those criteria, and complementing them with surveys to the campesinos, the ten communities were chosen.

Table 3. 2. Successfully Cases Selected

Campesino Community	Watershed	District	Province	Department	Families
Andamarca	Mayobamba	Carmen Salcedo	Lucanas	Ayacucho	100
Ayas	**Muylo**	**Tarma**	**Tarma**	**Junín**	**24**
Ccoricancha	Ccorimarca	Chinchero	Urubamba	Cusco	120
Cohechan	Jucusbamba	Conila	Luya	Amazonas	65
El Aliso	Namora	Namora	Cajamarca	Cajamarca	60
Hatun Suclla	Chanchas	Pucará	Huancayo	Junín	130
Molino Pampa	Ventilla	Molinopampa	Chachapoyas	Amazonas	113
Posoccoy	Chumbao	Talavera	Andahuaylas	Apurimac	80
San Rafael de Millpo	Cochatambo	Chinchao	Huánuco	Huánuco	50
Yaureccan	Ahuatario	Locroja	Churcampa	Huancavelica	167

Source: PRONAMACHCS (2002).

Most of these watersheds belong to the special sub project Intensive Management of Altoandina Micro-watersheds: MIMA. MIMA has the purpose of developing sustainable proposals for integrated management and participation in pilot watersheds. Those pilot watersheds will be replicated in other watersheds in PRONAMACHCS, within the scope of Peru-Sierra Natural Resources Management and Poverty Alleviation Project.

According the Assessment of successful cases in the Scope of Peru-Sierra Natural Resources Management and Poverty Alleviation, the project got good economic results, and also reported an increase in the income of the families. The Table 3.3 shows a summary of the economic results, increase in production value, benefits, and Net Income per capita.

Table 3. 3. Economic Results Indicators

Community	RESULT INDICATORS (Thousand U.S.$/year)						INCOME U.S. $/capita/year		
	INVESTMENTS		PRODUCTION VALUE		BENEFITS				
	Project	Contribution	Without Project	With Project	Without Project	With Project	Without Project	With Project	
Andamarca	128	11	38	90	27	66	68	165	
Ayas	**101**	**5**	**15**	**35**	**13**	**31**	**107**	**254**	
Ccoricancha	99	64	46	142	44	116	92	242	
Cohechan	57	6	93	199	69	128	265	492	
El Aliso	55	12	17	28	18	25	*75*	*104*	
Hatun Suclla	90	18	74	93	57	65	*110*	*125*	
Molino Pampa	70	17	56	132	33	98	73	217	
Posoccoy	47	11	46	62	51	63	159	197	
Señor de Millpo	153	5	72	134	60	101	300	505	
Yaureccan	65	19	22	109	17	71	25	106	
TOTAL	**865**	**168**	**479**	**1024**	**389**	**764**	**127.4**	**240.7**	Average

Source: PRONAMACHCS (2002)

The Benefit is considered as total net income, including the value of auto consumption. The Net Income is calculated of the division of Benefit with the total population of each community. Only for Ayas the population is known = 122 persons, for the others, is considered 4 persons per family.

Even the relative success obtained, the report also give some recommendations that shows the weakness in the project. The most relevant are:

- It is necessary focalise the investments in small geographical areas, the scope of more than 125 watersheds disperse the efforts, this have incidence in the effectiveness and efficiency of the activities.
- It is necessary to have previous assessment reports about: natural resources, organisation of the community, availability of human resources, trade markets, among other aspects.
- Reinforcement of monitory and evaluation systems with community participation.

3.3 Case Study: Ayas Community

From the ten successful cases, one watershed was chosen for the purposes of this study. There was not a special criterion for the selection, only the logistic facilities.

The Campesino organisation chosen is the **Ayas Community**.

Ayas Community is located in Muylo Watershed, over an area of 3189 hectares. The information related to this area is limited as most of the reports referred to the Muylo Watershed. Anyway it was possible to get some relevant information from the following documents:

- Soil Study of Muylo Watershed, MIMA – PRONAMACHCS. Tarma, March 2000
- Water Resources Inventory of Muylo – Mullucro watershed. Tarma, December 1999.
- Muylo – Mullucro watershed: agro economic and social diagnosis. Tarma, Nov. 1999.

This information was also complemented through the field information, and consultations with the main headquarters of PRONAMACHCS in Tarma.

3.3.1 Physical Description

Location and Boundaries

Table 3. 4. Location Ayas Community

Political Location:		*Geographical Location*	
Department:	Junín		
Province:	Tarma	Max level:	4250 meters above sea level
Basin:	Perene river	Min level:	3650 meters above sea level
Catchment:	Tarma river	Latitude S:	11°25'39" to 11°32'00"
Watershed:	Muylo – Ayas Lands	Longitude W:	75°43'00" to 75°47'00"

Boundaries

Sanyacancha, Ayas, and Duraznoic Communties make up part of the Muylo watershed area (about 5,700 hectares). The total area of Muylo watershed is approximately 17,693 ha.
The land belongs Ayas Community has an extension of 3,189 hectares (~18% of Muylo watershed area). It is necessary to emphasize that the borders of Ayas community have not been well defined yet.

Physical Features and Landforms

General Geology

The landscape is covered by lands formed by sedimentary and colluvial deposits. In this area grass prevails. In the study area Ayas watershed, there is evidence of a variety of rock formations, sedimentary, metamorphic and extrusive igneous. The ages range since Precambric to recent quaternary.

The lithostartigraphic units in this watershed are:

- Chambará Formation (Tr-ch).
  It has two defined parts. The lower part has diverse lithological characteristics and variable wide. The higher part belongs to a carbonate platform.
  The lower part has at the base layers of clay and gypsum, followed by coarse sandstone. The higher part has layers of dolomitic limestone and dolomites, from 0.20 m to 3m. Beds of calcareous-clay separate the layers. The carbonates colours range from light grey to black.
- Aramachay formation (Ji-a). It has defined two parts. The lower part has black calcareous shale, good laminated, with insertions of cherts. The higher part is more resistant, it doesn't have carbonates, and it has phosphatic shales, siliceous limolithies and cherts.
- Condorsinga Formation (Ji-c). It has uniform limestone's bank ranges from 0.20m to 3 m. In the middle and upper part of the formation there is dolomites.

Landforms and General Phisiography

Muylo watershed is a fluvial watershed, with seasonal flow in the main streams. It has low drainage density, with slow to moderate velocity response to a precipitation.

The surface is conformed by glacial deposits, the highest point rises 4 333 meters above sea level, the lowest point is located 3 400 meters above sea level. The landscape is full of hills, hillsides and creeks.

The top has wavy lithic bleedings, with slopes range from 4% to 20%.
The hillsides are in sloping ground, with lithic bleedings, with slopes range from 16% to 60%. The beds creek are full of alluvial and colluvial deposits. The side slopes range from 0% to 15%, and the longitudinal slope is high, range from 13% to 18%.

Erosion Problems

Soil losses in Muylo watershed happens because of natural causes like rain, and the physical characteristics of the soil. But human activity is accelerating the soil losses with bad agriculture activities such as furrows in the direction of the hillsides, overgrazing, and soil extraction for other activities.

Nevertheless, some people already work on soil conservation activities such as:

- Furrow infiltration and forestation.
- Slow formation terraces.
- Good agriculture practices such as furrows in contours, and crop rotation.

The following table shows the different levels of erosion in Ayas watershed, the values were obtained from the Soil Erosion plan showed in Annex I. The plan was elaborated on base of the Soil Study.

Table 3. 5 Soil Erosion Levels

Soil Erosion Level	Description	Area (hectares)
Non to Slight	Hydraulic erosion: laminar Slope ranged between 0% to 5% Located in the thalweg of the creek	31
Slight to Moderate	Hydraulic erosion: laminar and furrows Hillsides slope ranged between 6% to 30% Triggering factors: climate, hydrology, soils cover.	1399
Hard to Highest	Hydraulic erosion: laminar, furrows and ditches Hillsides slopes more than 20%. Triggering factors: climate, hydrology, and soils cover.	1759
	TOTAL	**3189**

Source: PRONAMACHCS – Tarma (2002).

Climate

There are scarce records about all the climatic parameters. The watershed has only one meteorological gauge station: Ayas. The Table 3.6 shows a compilation of Meteorological Information available from different sources.

In the watershed there are three defined seasons:

Dry Season: Months of May, June, July and August.
Intermediate Season: Months of September, October, November and April.
Wet or Raining Season: Months of December, January, February and March.

Table 3. 6. Meteorological Information

Parameter	Tarma[1] (1965– 1995)	SENAMHI[1] (1963-1980)	Ayas[2] (1999/2000-2000/2001)
Precipitation (mm)			
$P_{total\ annual\ average}$	401	383.5	471.10
P_{max}	75 (Mar)	69.3 (Mar)	84.9 (Jan)
P_{min}	2.6 (Jun)	2.4 (Jun)	3.6 (Jun)
Temperature (°C)			
$T_{media\ annual}$	12.3	--	7.99
$T_{max\ media\ annual}$	13.4 (Nov)	--	11.5 (Dec)
$T_{min\ media\ annual}$	10.8 (Jul)	--	5.20 (Aug)
T_{max}	14.4 (Nov)	20.20 (Nov)	21.7 (Dec)
T_{min}	10.1 (Jul)	3.10 (Jul)	-4.1 (Aug)
RH (%)			
$RH_{media\ annual}$	72	--	78.10
RH_{max}	76 (Jan)	--	87.6 (Feb)
RH_{min}	61 (Aug)	--	67.2 (Nov)

Sources: [1] Obando (1999), and [2] PRONAMACHCS – Tarma (2001).

Water Sources

The main sources of water of Ayas community come from the rain, the water that runs in the stream of Ayas creek, and the water that sprouts in some springs

Ayas Creek main characteristics:
- Total length: 8.55 km.
- With 3 springs
- Location:

Initial Point		End Point	
Longitude	75°45'35" W	Longitude	75°45'0.08" W
Latitude	11°31'40" S	Latitude	75°45'45.5" S
Level	4230 meters	Level	3630 meters

There are no records about the discharges in this stream.

The springs

Quinulapuquio spring:

It is located in the stream of Ayas creek. The water from this spring is stored in a small reservoir of 1000 m^3 capacity, for its subsequent use in grass irrigation downstream.

There are no records about discharges, only some referential observations, and one measurement that report a discharge of 10.24 l/s, in September of 1999 (Obando, 1999).

Shuyupuqio spring:

It is located to 1 km downstream of Quinualpuquio spring. The water from this spring is used to supply drinking water to Ayas community. There are no references about water quality; neither records about this source in the reports of reference. The only information given by PRONAMACHCS staff is the type of use.

Precipitation

The monthly average precipitation, and for different probabilities, was defined in base of isohyets methodology, the table 3.7 shows the values.

Table 3. 7. Precipitation

Month	Precipitation			
	Average	25%	50%	75%
January	100.6	119	103.9	89.5
February	96.9	116.3	92.9	75.1
March	90.5	110.3	85	69.2
April	47.4	55.7	48.5	31
May	27.5	38.6	23.4	12
June	10.4	21.8	5.8	0
July	8.7	12.5	7.7	2.1
August	27	35.1	23.7	13.8
Setember	38.7	50	38.7	27
October	69.6	82.7	66.8	45.9
November	50.3	65	49.2	41.7
December	87.4	100.8	87.3	68.8
Total (mm)	**655**	**807.8**	**632.9**	**476.1**

Source: Obando (1999)

The Table 3.8 shows the records of the new meteorological station Ayas. There is only available information from one year. Comparing the two tables, the minimum Precipitation occurs in June in both cases, and the highest values in the months of December to March.

Table 3. 8. Metheorological Station of Ayas 1999/2000 – 2000/2001

Month	T °C	T min °C	T max °C	T media °C	Evap mm/month	Precipitation mm/month	Instant P	Relative Humidity	Dew Point
Set	6.2	-1.2	17.2	8.0	108.2	36.8	0.02	74.8	1.3
Oct	9.1	0.8	18.2	9.5	129.5	27.8	0.05	72.1	3.7
Nov	10.1	-0.9	20.5	9.8	150.1	39.7	0.19	67.2	3.2
Dec	7	0.6	21.7	11.2	115.3	74.5	0.07	76.8	2.7
Jan	6.7	1.7	14	7.9	95.8	84.9	0.02	86.7	4.4
Feb	6.7	0.9	19.3	10.1	60.6	67.6	0.02	87.6	4.5
Mar	6.6	1.3	16.5	8.9	62.5	60.4	0.01	87.2	4.5
April	6.2	-0.7	14.9	7.1	92.9	37.2	0.02	83.8	3.4
May	6.2	-2.1	15.9	6.9	94.9	17.7	0.01	78.8	2.4
Jun	5.4	-3.6	15.2	5.8	88.8	3.6	0	75	0.8
Jul	5	-3.6	14.30	5.4	94	10.6	0	75.1	0.3
Aug	5.1	-4.1	14.6	5.3	104.1	10.3	0	72.1	-0.5
TOTAL					**1196.7**	**471.1**	**0.41**	**937.2**	**30.7**
Maximum	10.1	1.7	21.7	11.15	150.1	84.9	0.19	87.6	4.5
Minimum	5	-4.1	14	5.25	60.6	3.6	0	67.2	-0.5
Average	**6.7**	**-0.9**	**16.9**	**8.0**	**99.7**	**39.3**	**0.0**	**78.1**	**2.6**

Source: PRONAMACHCS - Tarma (2001)

Water Availability

There are no discharge records, but the discharges were estimated by PRONAMACHCS using the Methodology of Dr. L.R. Holdrige (zones life), defined by:

$$E = K \times P_p$$

Where:

E: Medium annual surface runoff, mm
K: Runoff coefficient, a dimensional.
Pp: Medium annual precipitation, mm.

INRENA (National Institute of Natural Resources) defines, the following values of precipitation and runoff coefficient for the life zones in Muylo watershed:

Table 3. 9. Classification according Zone Life through

ZONE LIFE	$P_{annual\ average}$ mm	Runoff Coefficient	Observation
Estepa Montano Tropical (e-MT)	375	0.25	Duraznoic area
Bósque húmedo – Montano Tropical (bh-MT)	750	0.30	Ayas area
Páramo muy humedo – Subalpino Tropical (pmh-SaT)	750	0.50	Ayas area

Source: Obando (1999)

Applying this methodology, considering the same runoff coefficients, the annual average runoff was calculated.

Table 3. 10. Ayas Watershed, Computation of Water Availability

	LIFE ZONE	SYMBOL	Area km^2	Runoff Coefficient	P average ann mm	Runoff averag ann mm	SURFACE RUNOFF Volume MMC	Discharge l/s
1	estepa-Montano Tropical	e-MT	0.00	0.25	375.00	93.75	0.00	0.00
2	bosque húmedo - Montano Tropical	bh-MT	0.89	0.33	750.00	247.50	0.22	7.00
3	páramo muy húmedo - Subalpino Tropical	pmh-SaT	31.00	0.50	750.00	375.00	11.63	369.80
	TOTAL		31.89				11.85	376.80

The annual average runoff will generate a discharge of 376.8 l/s in the area of Ayas.

In the Sierra of Peru, the common practice is the complementary irrigation, because in the wet season the rain water supply water for the farms, but in dry season water collected in wet season is used. In the Ayas watershed, for dry season they have the water from Quinualpuquio spring, with a discharge in the order of 10 l/s.

Water Quality

Chemical analysis of the water for agriculture was made, from the tests the results report that the water of the creeks are classified as C2S1 according irrigation aptitude, that's mean: moderate salinity, good for most of the crops, and without sodium.
But there is not more information about other aspects like BOD for instance. Anyway there is not pollution sources identified upstream of the watershed.

Land Use

The main use of the land is for agriculture and pasture. According the Soil Studies of Muylo watershed the actual land use does not match the potential land use, proposing an appropriate land use.

To define the areas that correspond to each use was difficult, because data inconsistence and scope scale. The soil studies report land use for Muylo watershed, then was necessary assume the boundaries of Ayas community and on base of the plans of the report calculate the different areas for Ayas, and make some assumptions. Then based in the report of Soil Studies, interviews with peoples, and consultation to PRONAMACHCS office, the areas were defined as is shown subsequently.

Actual Land Use

Based on the Soil Studies of Muylo micro-watershed (2000), the actual land use of Ayas Community is arranged as showed in the Table 3.11, and in the Plan 4 in the Annex I. If we compare this Table with the one showed in FARMOD sheets (Annex I) there are remarkable differences.

Not all the areas defined for the actual land use are being used in its all extension, for instance agriculture only uses 36 hectares from the 148.

Table 3. 11. Actual Land Use from Soil Study report

From Soil Study Report		
Land Use	**Areas in hectares**	
	Partial	**Total**
Agriculture		
Potato, barley, olluco (andean tuber crop)	31	
Potato, barley, peas, olluco	1.9	
Potato, barley, peas, olluco	75.6	
Potato, barley	39.5	148
Pastures		
Native grass	***610.9***	
Native grass (some furrow infiltration)	646.6	
Native grass (slow formation terracies)	413.6	1671.10
Forestation		
Eucalyptus and quinual	3.7	3.7
Protection		
Nule or scarce vegetation	***1366.2***	1366.20
TOTAL:		**3189.00**

Source: PRONAMACHCS – Tarma (2000). The areas in italics were calculated on base of the plan 4 for Ayas community.

The definitions of Land use are as follow:

Agriculture. This activity is developed in soils with different slopes: from smooth to steep. In some places there are terraces. The main crops are: potato, peas, barley, olluco (an Andean tuber crop).

Pastures. This activity is developed in steep slopes, scarce vegetation, and some areas have rocky outcrops.

Forestation. This activity is developed in flat lands and also in steep areas. In general these are used like barriers in the crop field.

Protection. This region has different slopes, ranging from flat to steeply. The slightly flat areas are located on the top of the mountains. These areas have rocky outcrops. The access to this area is very difficult.

Suitable Land Use

From the report of soils study, it is suggested to rearrange the land use, to use according soil characteristics and potentialities. A new "use" has been defined: Protection with native species. Then according that, information form PRONAMACHCS staff, the effective land use, the actual land use and new arrangement as Suitable land use is showed in the table 3.12

Table 3. 12. Table of Land Uses defined for this study

Land Use	"Effective"	"Actual"	Suitable
Agriculture	36	148	156
Pastures			
- Furrow Infiltration (*S.E.C.S.*)	83	83	160
- Others *(S.E.C.S.)* *	14	1568	14
- Milk Production	20	20	30
Forestry	4	4	132
Protection			
-Very eroded (X)	1343	1366	1343
-With Native species (X')	***1354***	0	1354
TOTAL	**2854**	**3189**	**3189**

S.E.C.S.: Soil erosion control structures.

In the land use defined like protection, the classification is defined as follow:
- Very eroded: With high density of outcrop rock, and scarce vegetation. X
- With Native Species: Land that can be protected by forestation with native species. Only includes some bushes and small trees. X'

In the annex I, the plan 5 shows this information.

Planned Land Use

For the purposes of this study based on the available information, the areas for actual (effective) use and for a future use are defined according the following table. The column "Spring" is referring to the reception area that influence the discharge in Quinualpuquio spring.

Table 3. 13. Plan of Land Use Areas

LAND USE	Present Area (Ha)			Future Area (Ha)		
	Spring Area	Out Spring Area	Total	Spring Area	Out Spring Area	Total
Pastures						
Low Grass (Milk Production)	0	20	20	0	30	30
Furrow Infiltration	83	0	83	114	46	160
Others (terracies, etc)	0	14	14	0	14	14
Forestry	0	4	4	0	132	132
Agriculture	0	36	36	0	156	156
Protection						
Very eroded (Protection) X	419	924	1343	419	924	1343
Native Species Forestry X'	467	887	1354	467	887	1354
		TOTAL	**2854**		**TOTAL**	**3189**

The protection areas were fixed at the same values, because there is not information about erosion process, and treatment of area X' through forestation with native species.
The future values of agriculture land, refers the possibility of big increase in this land use, but it will not be possible a growing in land use in this activity so big (more than 4 times the actual value). For the agriculture land use, further discussion is presented in the Social and Economic Description.

Water Demand

The main use of the water is for agriculture proposes. Then other uses are prioritised as following:

1. Agriculture
2. Domestic
3. Livestock

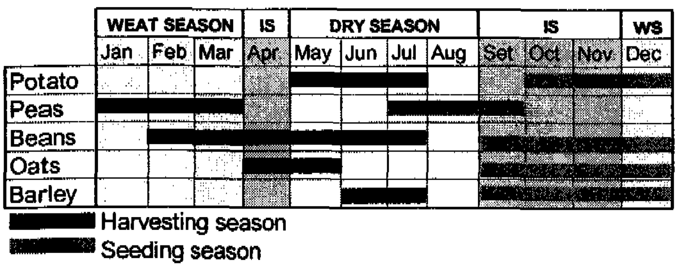
Agriculture:
It is considered the use for crop growing and also for grass seeded.

For the Crops:
According the area of effective use for agriculture defined by PRONAMACHCS, and the crop pattern, the water requirement was estimated in around 347 mm/year, or approximately **125,000 m^3/year** for the 36 hectares.

Table 3. 14. Water Crop Requirements and Crop Pattern

Crop	Irrigation by	Seeded Area (ha)	CWR (mm/season)
Potato	flooding	14	159
Peas	flooding	7	52
Beans	flooding	3	26
Oat	Rainfed	3	27
Barley	Rainfed	9	83
	Total	36	**347**

Table elaborated using CROPWAT.



Source: PRONAMACHCS – Tarma (2002)

For the grass seeded:

Considering:
For Rye Grass CWR: 500 mm (Hannaway, 1999)
Irrigated area: 20 hectares
Irrigation efficiency 70% (Rogers, 1997)

The water requirement is around **143,000 m³/year**

Then Agriculture Total water demand is: **268,000 m³/year**

Domestic:

Water supply average in Peru is: 287 l/capita/day (MINAG, 1995).
Ayas Community Population: 122 people

The average will be about 287 x 122 x 365 / 1000 = **12,780 m³/year**

Livestock:

The following table shows the computation to estimate the water demand of livestock. Only the big groups are considered. The consumption for cows and sheeps, are according Cadwallader and Stauffer (1997). About vicunas and alpacas, there is not reference about water consumption, but an estimation based on the values required for cows and sheep, of 0.05 m³/day/unit was considered.

Table 3. 15 Livestock Water Consumption

Livestock	Units	Consumption		
		m³/day/unit	m³/year/unit	m³/year
Vicunas	100	0.050	18.25	1825
Alpacas	120	0.050	18.25	2190
Cows	137	0.094	34.31	4700
Sheeps	1200	0.015	5.475	6570
			TOTAL	15285

Total Demand

Table 3. 16 Total Demand

Use	Demand m³/year
Agriculture	268 000
Domestic	12 780
Livestock	15 285
TOTAL	**296 000**

The Total demand is approximately = 296 000 m³/year = 9 l/s
The total water availability calculated in table 3.10, is around = 376 l/s

In general terms, for the actual conditions, there will not be problem of deficit if there is a good watershed management. Even if there is an extension on the agriculture land (4 times the actual one), it expected there would no be shortages.

3.3.2 Social and Economic Description

Social System

Ayas is a campesinos community created from the SAIS (Agriculture Society of Social Interest) Ramón Castilla. Ayas made up of 27 families. Of these at present there are only 18 active families, 3 left the community, 4 families are retired, and 2 families have license and are living in the city.
The total population of Ayas Community is of 122 people, as it is shown in the Table 3.17

Table 3. 17. Family Composition Ayas Community

Family head	27
Spouse	17
Sons	42
Daugthers	32
Grand parents	0
Grand children	3
Others	1
TOTAL	**122**

Source: Rojas (1999)

Campesinos communities (comunidades campesinas) are recognised in the Political Constitution of the Peruvian Government as legal persons. They are autonomous in their organization, in the communal work and in the use and the free disposition of their lands, as well as in the economic and administrative issues, inside the framework that law establishes. The property of their lands is imprescriptibly, but not in the case of abandonment. The State respects the cultural identity of the Native and Campesinos Communities. The legal framework of communities in Peru are based on the Political Constitution of Peru, The General Law of Campesinos Communities – Law 24656, the Law of Communal ownership – Law 24657.

Community Organization and Community Structure

Community organizations in the Sierra evolve around land ownership and cultural traditions. Top authority lays with the General Assembly where the main decisions are taken; a board of managers integrate a "Junta Directiva" including a President, a Vice-President, a Treasurer, Deputy and a Supervisor; this organisation also incorporates municipal authorities related to the political structure of the country such as the "Teniente Gobernador"and the "Agente Municipal". All members are elected democratically in a general assembly attended not only by all "comuneros" but their families, including young people and children. Traditional organizations have proven to respond to requirements of different public and private programs. The community creates special committees of elected members in charge of each particular program; such as: conservation, irrigation, water and electricity committees.

Infrastructure Facilities

Characteristics of a Typical House:
Walls made by blocks of mud with stones with thatched roof and compacted soil floor, water supply installation, but no sewage system.

Health Services:
The community does not have health facilities; they have to go to Duraznoic 4 km away from Ayas, where there is a health centre.

Education:
One school, that gives primary education. The school is in charge of one teacher, who attends twenty students.

Transportation:
There is not daily public transportation service to Ayas.

Drinking water supply:
The water for domestic use is supplied from Shuyupuqio spring; it is not clear how the water is distributed. There is no information about drinking water supply in the reports from PRONAMACHCS.

Energy:
Ayas community has electricity. There is no more information about tariffs, or number of users in the reports from PRONAMACHCS.

Communication
By radio, there are no phone line installations.

Institutions and NGOs participating in Ayas watershed

- CONACS (National Council of South American Camels): Providing technical advise in South American camels
- UNCP (National University of the Centre of Peru). Researches in agriculture and livestock, genetic improvement of cows.
- PRONAA (National Program of Food Support): Giving social assistance, providing food.
- Tarma Provincial Municipality: With social assistance, through the program "glass of milk".

Economic System

Activity Production

- Milk Production

One the most developed activities with high technology. The community use sprinkler irrigation system to irrigate grasslands and improve the production of grass.

Resources
Grass land area: 20 hectares with sprinkler system irrigation, able to extend to 30 hectares.
Grass yield: the yield of green dry mater is still in research; at present the yield is around 21,500 kilograms per hectare. The grass cultivated is a combination of english rye grass, red clover, white clover, dactylis glomerate and festuca arundinacea. The water to irrigate comes from the Quinualpuqio water storage.
Cattle: there are 20 cows, and 117 no productive cattle. There is no more information about this.

Production
The Milk production is improved, from a yield of 3.5 to 3.8 l/cow/day, at present the milk production is of 8.0 l/cow/day (PRONAMACHCS-Tarma, 2000).
The total production is around 20 x 8 = 160 l/day = 58,400 l/year
Market Price
Milk Price in Peru = 0.24 U.S.$/l (CEPES, 2003).

Commercialisation
The commercialisation of the production is through daily products as cheese, butter and yogurt.

The approach value production because of this activity is around:

Income milk	=	Milk production x Milk Price	
	=	58,400 l/year x 0.24 U.S. $/l	= **14 000 U.S. $/year**

- Fibre Production

The most important, is the vicuna fibre production, but its commercialisation is restricted by the CITES.

Vicunas (vicugna vicugna) are wild camelids that live in the high regions of the Andes, between 3 000 to 4 600 meters above sea level. The countries that hosted these animals are: Ecuador, Peru, Chile, and Argentina. Peru is the country with the largest population (102000 in 1998). The commercial interest put vicuna to the verge of extinction due to illegal hunting, declining the population in Peru drastically between 1960 to 1970, leading the listing of this species in the appendix I of CITES and the imposition of restrictions on international trade in vicuna fibre and products.

Current vicunas are listed in the appendix II of CITES. Appendix II lists species that are not necessarily now threatened with extinction but that may become so unless trade is closely controlled

But since 1992, since terrorism activities stop, the government apply the policy to take care of this animals, the only owners in Peru of vicunas are the Campesinos Communities, only them through the National Vicuna Society can trade vicuna fibre.

Vicunas are managed in the wild, only captured to shorn, and then released. Andean communities capture the vicunas communally by surrounding them and leading them to move towards a funnel shaped mesh. This process, called chaku, draws on methods practises by the Incas. Once in the funnel, vicunas are taken one by one, shorn and released.

Resources
Pastures areas: Vicunas and alpacas are fed with native pastures growing in the high lands. In Ayas these areas are made up by:

- Cultivated native grass area on the furrow infiltration, at present around 3 hectares, able to expand to 10 hectares, or maximum 20 hectares in the next 5 years. Because the ability of increase this kind of land use in Ayas community is estimated around 7 hectares per year, based on PORNAMACHCS activity indicators.
- No cultivated native grass area on the furrow infiltration, at present around 80 hectares, able to expand to 160 hectares. This land use can be extended more because they use machinery to do it.
- Areas with other similar infrastructure for soil erosion control, like terraces, around 14 hectares.
- Protection areas, around 2697 hectares.

Supportability: It means the quantity of south camelids (vicunas and alpacas) can be fed per hectare of land. It varies according land management and soil quality.

Following some general values and the values adopted for Ayas community are presented.

Table 3. 18 Supportability of Alpacas

Type of Land	Supportability (alpacas/hectare)
Native pastures	0.5
With seeded grass	3

Source: PRODASA, 2002.

Table 3. 19 Supportability of Vicunas

Type of Land	Supportability (vicunas/hectare)
Native pastures	0.2 to 0.6

Source: Lichtenstein, 2002.

Table 3. 20 Supportability for Camels in Ayas

Type of Land	Supportability (camels/hectare)
Cultivated grass	3
Native grass managed	1.5
Native pastures X'	0.2
Native pastures in eroded area X	0.05

Number of animals: 100 vicunas and 200 alpacas.

Production:
Vicunas produce 220 grams of fibre each two years, then 110 g/year (Toscano, 2002)
Alpacas 3,632 grams of fibre each year, then 3.63 k/year. (Davis, 2000)
The annual production is around:

Vicuna fibre: 100 x 0.11 = 11 k/year
Alpaca fibre: 200 x 3.63 = 726 k/year

Market Price: Vicunas fibre 308 U.S. $/k
Alpacas fibre 3.5 U.S.$/k

Commercialisation
Vicuna fibre commercialisation is through the National Society of vicunas, they collect the fibre from all the country and sell it to an enterprise chosen via International Competence.

This is one of the activities more profitable, according many studies, and the community have to take advantage of this, combining this activity with soil erosion management. This species do not produce soil erosion, their foot are provided by special tripe and will not produce soil losses.

The approach value production because of this activity is around:

Income fibre = Fibre production x Fibre Price
= 11 k/year x 308 U.S. $/k + 726 k/year x 3.5 U.S. $/k = **5 900 U.S. $/year**

- Agriculture Production

The information about the agriculture production is contradictory; there is not certainty about the area effective used for this activity. From the information provided by PRONAMACHCS, the area under agriculture was estimated around 36 hectares, as is showed in Table 3.21

Resources

Land: This activity is made combining family production and communal production. The actual area used by agriculture is shown in the table 3.21. To extend the area depends very much of the labour effort that the campesinos are willing to do. According the report of ten successful cases, in the last 5 years they increase the land use for agriculture en 30% (from 27 to 36 hectares).

Water: Partially rainfed, and partial irrigated. About the water for irrigation there is no information available.

Agriculture Inputs: seeds, fertilizers and pesticides. The seeds and fertilizers are provided by PRONAMACHCS. The mechanism of provision is providing seeds to the campesinos to incentive its participation in the Project Peru-Sierra Natural resources management.

Production

The yields improve respect the previous one. The values shown in table 3.22 are the one provided by PRONAMACHCS in 2003.

Market Price

The prices were provided also by PRONAMACHCS in 2003, the values are shown in the table 3.22.

Commercialisation

There is no much information about how is the mechanism of commercialisation.

Table 3. 21 Agriculture Production Land and Crops

Crop	Irrigation by	Family		Community	Total
		Ha/fam	Total		
Potato	flooding	0.5	12	2.0	14
Peas	flooding	0.25	6	0.5	7
Beans	flooding	0.12	2.88	0.5	3
Oat	Rainfed	0	0	3.0	3
Barley	Rainfed	0.25	6	3.0	9
		1.12		TOTAL	36

Table 3. 22 Agriculture Production Income

Crop	Yield[1] kg/ha	Crop Area ha	Production kg	To sell %	Prices S/. / kg	Income s/.
Potato	12000	14	168000	60	0.8	80640
Peas	1500	7	9750	80	1.2	9360
Beans	2000	3	6820	80	0.8	4365
Oat	1200	3	3600	0	0.6	0
Barley	1600	9	14400	20	0.6	1728

Agriculture Productivity

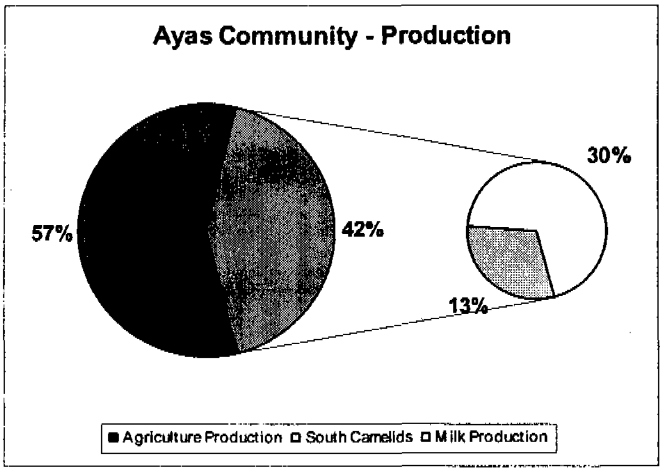
Total (S/.)	96093
Total (US$)	27145

Total (S/. /ha)	2676
Total (US$/ha)	756

Yield[1]: Are the actual yields by the implementation of the project. If we compare this ranges with the ones referred by FAO, are quite low. This means that can be improve much better.

The approach value production because of this activity is around **27 000 U.S. $/year**

Summary of Activity Production



The total production value because productive activities is around **46,000 US$/year.** The total production value according the table 3.3 is around **35,000 US$/year**.
The difference reveals the lack of information, and uncertainty.

From the figure 3.1, it can be identified that agriculture is the main productive activity that generate more than 58% of the Total Production. From livestock, the most productive is milk production.

Figure 3. 1 Ayas community Production in percentages

3.3.3 Valued Features and Activities

Among the features and activities that promote the management of the watershed can be considered the following:

- Communities have the policy of free labour in support of the community. This is a good advantage, because in this way they can maintenance the infrastructure, and with the results obtained at the moment they are enthusiastic in what they can do in the future.
- Localisation of Ayas watershed in high lands, reduce conflicts problems, and pollution is not a main problem
- Localisation near to Lima the capital city facilitates the access to markets.

3.3.4 Watershed management

Watershed management of Ayas is leaded by PRONAMACHCS under the scope of the Peru-Sierra Natural Resources management and poverty alleviation project. Objectives, strategies, investments and policies of watershed management, are all under the scope of this project.

Following a brief description of the watershed system and the strategy implemented.

Watershed system

In the high part of the watershed furrow infiltration have been built to reduce the runoff and to control the erosion, besides has been sown native grass in some of these areas. The sown grass serves to feed alpacas and vicunas. The grass cultivation is complemented with the fencing of the same in the phase of growth to avoid that grass in growth are eaten for the alpacas and vicunas.
Furrow infiltration reduces runoff and increases the infiltration, campesinos report an increment of the discharge of the spring Quinualpuquio in dry season, and are presumed that it is for effect of the furrow infiltration.
Other structures for soil erosion control as terraces exist also, which have the same effect of runoff reduction and increment of infiltration, but do not be related to the discharges in Quinualpuquio.

The water from Quinualpuquio spring is diverted by a channel into a reservoir for its storage and subsequent use in grass irrigation in the lower part of the watershed. The grass is to feed the cattle, special to the cows that produce milk. This grass is irrigated using sprinklers manipulated by the campesinos. This activity is combined with the fencing to avoid that grass in growth be eaten by the cows. These activities of soil erosion control, water storage and land management have permitted to initiate a new nonexistent productive activity in the watershed, milk production and daily products commercialisation.
Besides the mentioned benefits, soil erosion control activities uphill reducing soil losses allow the rehabilitation of downhill land for its use in agriculture.
The agriculture land are located most in the low part of the watershed, it is basically rain fed.

There is no more information about the other land use and water use in the watershed, because the activities are concentrated and related on Soil Erosion Control.

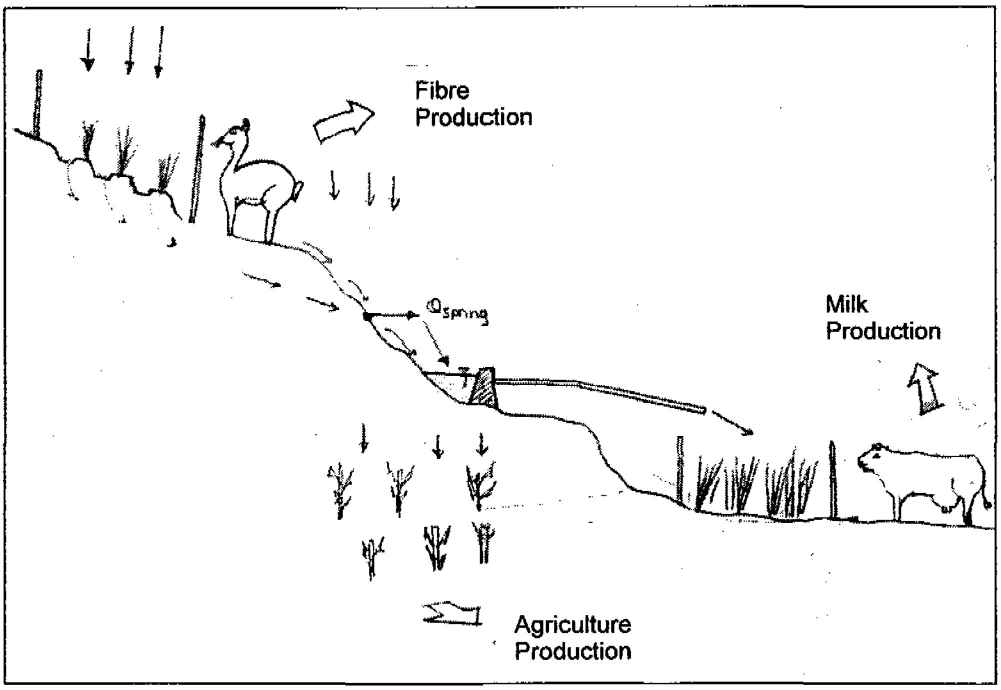


Figure 3. 2 Watershed System Scheme

Strategy

As it was shown in the watershed system, the actual activities of the watershed management are focussed on build and maintenance of soil erosion structures, and its use for agriculture and livestock, combined with good practices of land use and reforestation. All the activities are part of the strategy implemented by PRONAMACHCS under the scope of Peru-Sierra natural resources management and poverty alleviation project, in order to achieve the main objective: Poverty alleviation.

The project's overall strategy consists of a participative community natural resources management and land use planning.

The technical strategy aims at: (i) adjusting land use to soil characteristics, (ii) increasing production on fertile lands and, where not possible, convert marginal erosion-prone soils into stable agricultural soils through terracing; (iii) opening the soil infrastructure to maximize water infiltration through introduction of adequate soil preparation and cultivation techniques; (iv) increasing soil cover through agricultural and (agro) forestry practices which at the same time increase income; and (v) optimising water use for productive and other purposes through construction of small irrigation schemes.

The operational strategy consists of a rural extension system, organized by PRONAMACHCS, which would help the communities prepare and implement the rural investments, and finance the rural investment costs with the proceeds of the project. The communities would contribute in unpaid labour. The project will train the rural communities to foster self-management.

In order to fulfil the strategies mentioned before, in Ayas the following activities were carried out:

Soil Conservation Infrastructure Works (construction of terraces, water infiltration furrows)
With the purpose to control runoff and erosion, and to foster infiltration in rainy season, the following activities were executed:

- Furrow Infiltration, made with machinery by PRONAMACHCS, in a total area of 83 hectares. With native grass cultivation on 3 hectares of this area.
- Terraces in an extension of 0.3 hectares
- Slow Formation terraces in an extension of 2.3 hectares
- Fencing of areas with grass cultivated, to protect the growing grass.

Small-scale irrigation works and Improvement of agriculture practices (Agricultural Inputs provision)
With the purpose to expand grass production, the following activities were carried:

- Reservoir of earth, capacity storage 1000 m^3
- Installation of Sprinkler Irrigation system for 20 hectares, with possibility to extend tills 30 hectares.
- Cultivation of grass to improve milk production.
- Provision of seeds and fertilisers from PRONAMACHCS.

Reforestation and agro forestry
With the purpose to reduce soil erosion, protect farm fields and promote timber production, the following activities were carried:

- Establishment of plantations with native species.
- Plants production in a nursery

Rural community Strengthening
The strengthening of the community will be promoted by participation, technical and managerial capacity. The activities implemented by PRONAMACHCS in this aspect are presented as follow:

- Courses for campesinos producers: 19 in 5 years
- Courses for campesinos promoters: 2 in 5 years
- Incentive systems for participation via provision of seeds and fertilisers.

It is important to highlight here that the Project is considered be sustainable if there is community participation. Through labour contribution, the frequency is from1 day per week to the maximum of 3 days per week.

There is not more information about this activities, that the mentioned already.

3.3.5 Analysis of Available Data

All the data collected from PRONAMACHCS was made in relative short time, some extra information was acquired through mail with the collaboration of Mr. Soza, Coordinator of the offices in Tarma.

The data is dispersed and there are many contradictions about the areas of land use, or even there is not information about that.

Following a summary of the data and the problems related to each one.

- Insufficient detail: Because the big scope of the project (more than 125 watersheds) many reports are made by regions, including two or more watersheds, for instance reports about hydraulic resources in Muylo and Mullucro.
- Progresses reports are focussed in present the results in terms of activity indicators. There are not reports referring impact indicators.
- The boundaries of Ayas Community are not defined. There is not a base plan showing the area that belongs Ayas community.
- The areas of soil conservation structures are not defined. Only the areas for furrow infiltration.
- The land use of the area above the spring Quinualpuquio is not defined.

For the purposes of this study it was necessary to make some assumptions, and estimate values based in the information available, reports, and interviews on the field and via e-mail. All these estimations and assumptions are presented in this chapter, with the references and assumptions taken.

4 Building the Bayesian Network

As it was mentioned before, Bayesian Network is a tool that can be used to build a Decision Support System for watershed management, according Cain (1999) there are two ways to do it:

- Providing a mathematical optimal decision on basis of the information provided by the BN
- Or promoting and improving the understanding of the environmental system, leaving the decision makers to reach their own conclusions.

The present study is based on the second approach, for that reason the Bayesian Network will represent the system with their key activities. The Bayesian Network built represents the watershed system according the author beliefs and understanding, the building process was based on the methodology that is described at follows

4.1 Methodology

The methodology followed is based on the general guidelines given by Cain (2001) and Moriarty (2002a), and the author experiences acquired in the process.
Basically the methodology is a cycling process of developing, testing and refining. First it is necessary to develop the model, then test how this work, if it is representing the system as was understood, if it does not, is necessary refine, and make some corrections or adjustments, and repeat the process until being satisfied with the results or representation.

4.1.1 Developing the model

The model have to represent the watershed system, then during this process always think in to model the system with the key activities and objectives to achieve, to get a good representation of the system.

Defining the objectives

The objectives are things that will be affected through the watershed management; things to improve or to prevent of becoming worst.

Each watershed has different problems to face, for instance floods, water shortages or soil erosion. Depending on the problems faced, the objectives presented will be different.

The identification of objectives will help to identify the activities related to it.

Identifying key activities

Answering the next questions will help identify the key activities:

- What are the activities in the watershed, and how this activities influence the identified objectives?
- How these activities are linked to the objective as among them?

In the Bayesian Network the activities are represented through different variables (nodes), and the arrangement of them with the objectives can be done following the general Network structure suggested by Cain (2001) in the application to natural resources management.
The structure of the general Network presented in the figure 4.1 is only a suggestion, where the arrows show how the categories are likely to be linked. This diagram is only a guideline for the Network to build, do not be constrained by this, and don not forgets that Bayesian Networks are not flow diagrams.

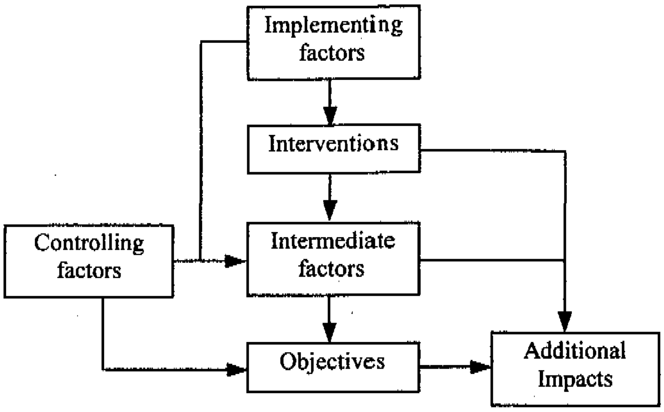


Figure 4. 1. General Network Structure

The following table shows the definitions and related examples to the categories variables of the general network structure

Table 4. 1. Categories of variables in Bayesian Networks

Category	Description	Examples
Objectives	Things to affect through the watershed management. To prevent or improve.	Agricultural productivity, income.
Interventions	Things to implement in order to achieve the objectives.	Train farmers, subsidise agricultural inputs
Intermediate Factors	Factors which link objectives and interventions.	Yield
Controlling Factors	Factors that control the environmental system at the work scale, in some way.	Population, rainfall, etc
Implementation Factors	Factors which directly affect whether the intervention can be successfully implemented both immediately and in the future	Land availability
Additional impacts	Factors which are changed as a result of interventions that do not affect anything else in the environmental system	

Source: Cain (2001)

Building a causality network with the activities identified, arranged as the figure 4.1 suggest, will help in the next step.

Defining Nodes and Nodes states

The variables identified, will be represented as nodes in the Bayesian Network. The nodes can represent any physical, social, economic or institutional factor, as Cain (2001) states:
"They can present tangible things like water, or intangible concepts such as a consensus among stakeholders. They can represent quantities, a property or movement of those things. They can also represent actions".

But the node it is not only a representation of a variable, represents also states of nature. To select the states for each variable, it is helpful think how to describe the actual state of the variable, how do you expect will change the variable state under the management plan, if will be any intermediate state? Anyway after testing the model the node states can be arranged better.

Defining relationships between nodes

The model will not be complete with out a definition of causal relationship between them.

The relationships will be defined filling in conditional probability tables, through the different sources as expert opinion, empirical data, or mathematical model that can be a simple equation. It is necessary to put much attention to the source of information, and carry a file with the assumptions made, the conditions and criteria assumed at the moment of filling the CPT's, this will help in the Testing and refining process when is necessary change something or, when further explanation is required from people not involved in the building process.

4.1.2 Testing

After the model is finish, then a testing process is required to verify if it is representing the beliefs and understanding about the watershed.

Testing of the model will be done through systematic changes in the nodes:
- First change the different state of each node, and observe what are the changes in the objective node.
- Change the states of the objective nodes, and observe what happens in the other nodes, especially in the controlling nodes.

Put attention to the links, verify if the link connections are adequate or logic, try to find if there are missing links.
Put attention to the node states, are well represented, identify unnecessary states.

After the testing process, if any change is necessary go to the next step, refine the model.

4.1.3 Refining

After testing the model, all the identified changes to do will be part of the refining process.
Always try to represent what is happening in the physical world, in the field, according your beliefs and understanding about the watershed system.

4.2 Developing the Bayesian Network for Ayas Watershed

The Bayesian Network was developed in order to represent current understanding and available information for what the author believes are the key processes linking activities of watershed management developed by PRONAMACHCS with the Community and the Objective of Poverty alleviation.
The development of the network was carried out following the steps of the methodology explained before. A description of the process is presented below.

4.2.1 Developing the model

Defining the objectives
The objective defined by the Project is: poverty alleviation, trough a productive and sustainable use of the natural resources. Another objective of the project is the strengthening of the community with participation of the community, looking for autonomy.

To represent those objectives the following variables were chosen:
In the first trial model:

- Poverty Alleviation.
- Natural Sustainability.

Identifying key activities

What are the activities in the watershed, and how this activities influence the identified objectives? The activities identified are as it was mentioned in the chapter 3:

- Soil Conservation Measures: Infrastructure (work conservation and infrastructure) and non-Infrastructure (management).
- Agricultural Inputs: seeds and fertilizers
- Productive activities: Livestock (Milk production and Special fibre production) and Agriculture: auto consumption and commercialisation
- Community Strengthening Component: Participation of the community, assistance to the trainings.

All those activities can be qualified as Interventions and Intermediate factors.

The other variables qualified as controlling factors are:

- Precipitation or rainfall.
- Soil quality: permeability.
- Markets: variation in prices.

With the objectives and activities identified the causality network showed in the next figure was elaborated. The causality network shown in the figure 4.2 is the first one trial, after the process of testing and refining the final Network change as it shown in the figure 4.3

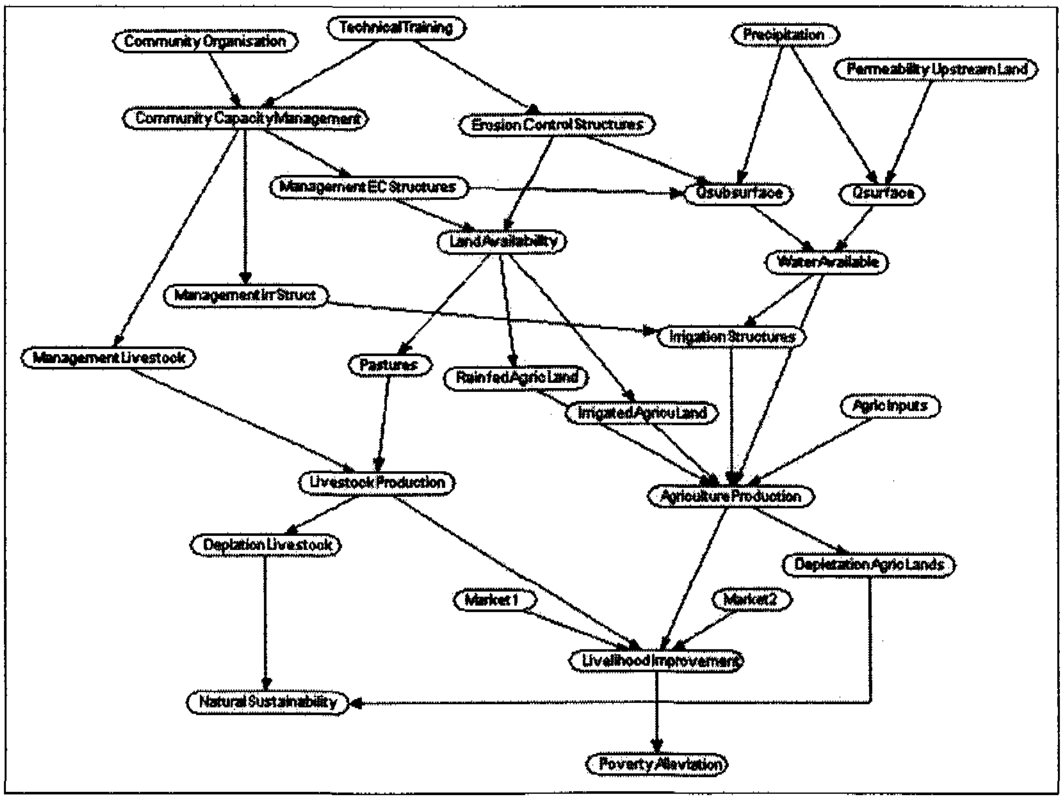


Figure 4. 2 Preliminary Causality Network – Ayas Watershed.

Figure 4. 3 Final Bayesian Network Modelled Ayas Watershed System

Defining Nodes and Nodes States

Following from the final model of Bayesian Network (figure 4.3), the definitions of the objectives and some controlling factors nodes and their respective states are presented. For the other nodes refer to the Annex II.

In the final model:
Objective Nodes

- *Sustainability*, in sense of the Project Sustainability. Related with the level of income that will give to the community auto-financing capacity, and labour contribution as it is defined by the Project. This variable has two states: high and low. The parent nodes are: *Income* and *Labour Contribution*.
- *Income*, was chosen as indicator of poverty alleviation, because is the only measure of that referred in the Report of assessment of successful cases. The states are ranged according the actual income, the target poverty income, and the maximum income if a good development of economic activities is reached. The parent node is *Total Benefits*.
- *Autonomy*, of the community in sense of managerial, technical and financing capacity. Autonomy to manage the watershed without guidance of an external Institution or Organisation. This variable has two states: high and low. The parent nodes are *Autofinancing Capacity* and *Management Capacity*.
- *Management Capacity*, capability of the community to manage by themselves the watershed in sense of technical and administrative capacity. The states are Strong or weak. The parent nodes are *Participation* and *Technical Capacity*.

Controlling Factors

- *Rainfall*, annual rainfall that can fall, the ranges are arranged according the values shown in the tables 3.7 and 3.9 referred at the average (600 mm/year) and maximum values (more than 800 mm/year).
- *Labour contribution*, defined as the unpaid labour in activities related with the watershed management. As was mentioned in the chapter three, the minimum labour contribution is of one day per week, and the maximum of 3 days per week. Then the states were defined in three ranges: Low with 1 day/week, medium with 2 days/week and high with 3 days per week.
- *Autofinancing Capacity*, defined as being able to access credits and loans. At the beginning the idea was link this node with the node Income, but it was not possible because it will create a loop in the Network, that can not be stand it by the model.
- *PRONAMACHCS*, it is a kind of switch to show the influence of the Institution oh the watershed system. Sates are Intervention and No. Are linked with the main activities they realise in the watershed: training courses, land management, and Agricultural Input provision.
- Beneficiaries,
- Attendance,
- Fiber vicuna price

Controlling factors related to Land use
The nodes represent the land use defined in the chapter 3 according the table 3. 13. These nodes are: *Available Area1, Grass area to irrigate, Cultivated Area* and *Protection Area (X'), and Camelids in Area(X).*

Intervention factors: *Training Courses, Agr. Inputs Provisions,* and *Irrigation efficiency.*

Implementation factors: *Available Area2,* and *Area with other Similar Structures*

The other nodes are considered Intermediate factors, there are no Additional impacts considered in the Bayesian Network.

Defining Relationships between nodes

The relationships between the nodes are defined filling the conditional probability table CPT. In order to fill the CPT, all the source of information was used, including expert opinion, empirical data, reference data from researchers, and the author beliefs. In the annex II, there is a summary of the CPT used for the model, and the calculations made for some cases. In the next section more details about filling CPT is presented.

4.2.2 Filing Conditional Probability Tables CPTs

To fill a CPT is necessary information about the variables involved, the sources of information to fill were defined in chapter 2 as:

- Empirical Data. Data collected by direct measurement.
- Participatory Input. Data collected through stakeholder elicitation.
- Models. Output from process-based models calibrated using data collected by direct measures, could be also a simple one expressed by an equation.
- Expert Opinion. Academic 'expert' opinion based on theoretical calculation or best judgement.

Following the description of the filling of some CPTs using different kind of sources.

From expert opinion

CPT for the node *Available Water*

Available Water, it refers to the amount of water expected at Quinualpuquio spring related to the furrow infiltration treatment upstream under different conditions of rainfall.
Parents Node: *Rainfall* and *% Treated Area1*.
The node Rainfall was explained already. About the node *%Treated Area1*, it reflects the percentage of area treated with furrow infiltration in the area of reception that infiltrate into the spring. The percentage is related to the total area able to be treated with furrow infiltration.

In the process of filling the CPT, it was found that there was not enough information to do it, because there are no records of discharges in the spring, neither about soil characteristics, or infiltration rates in limestones (because the karst formation). After a failed literature search about general rates of infiltration in karst formation, it was decided to look for an alternative way of filling the CPT, through consultation for expert opinion.

Then a consultation to Dr. Batchelor, an expert with experience in watershed management with knowledge about Bayesian Network was made via e-mail.

In this case of expert opinion, it is necessary give to the expert some information, and brief explanation about the meaning of the CPT and variables involved, and prepare a table to be filled. In the annex II the letter sent to Dr. Batchelor and the reply is presented. The CPT filled by Batchelor is shown in the Table 4.2

The two first columns of left are the parent nodes, the other ones are different states of the child node: the percentage of change in the spring discharge. In bold, the numbers filled by Batchelor.
The first row of the last column means, 90% of probability of increase in the discharge of the spring in dry season, if the area treated is in the range 0 to 25%, and there is an annual rainfall in the range of 0 to 600 mm.

Table 4. 2 CPT filled by Batchelor

Batchelor CPT (original)

Catchement area treated	Rainfall mm/year	Increase Qspring in dry season (%)			
		0 - 10	10 - 30	30 - 60	60 - 100
0 - 25	0-600	90	10	0	0
0 - 25	600-750	85	15	0	0
0 - 25	750-900	80	15	5	0
25 - 50	0-600	70	15	15	0
25 - 50	600-750	65	30	5	0
25 - 50	750-900	60	30	10	5
50 - 75	0-600	50	25	5	0
50 - 75	600-750	45	45	10	5
50 - 75	750-900	40	40	15	10
75 - 100	0-600	30	35	15	5
75 - 100	600-750	25	50	20	10
75 - 100	750-900	20	45	25	15

Table 4. 3 CPT – Available Water

Treated Area (%)	Rainfall (mm/year)	Available Water m^3/year		
		50000	300000	1000000
0-25	0-600	100	0	0
0-25	600-750	0	90	10
0-25	750-900	0	0	100
25-50	0-600	100	0	0
25-50	600-750	0	95	5
25-50	750-900	0	0	100
50-75	0-600	100	0	0
50-75	600-750	0	90	10
50-75	750-900	0	0	100
75-100	0-600	100	0	0
75-100	600-750	0	75	25
75-100	750-900	0	0	100

After the consultation was made, the author realised that it will better express the *Available water* in terms of volume, and a calculation in base of the CPT filled by Batchelor was made.
The CPT used in the final model is the one presented in the Table 4.3. All the process of calculation is presented in the Annex II.

From Models

The models can be very complicated or simple ones expressed only by one formula. In this case study the models used are simple formulas. Following one of the CPTs filled using formulas.

CPT for node *Irrigated grass area*

Irrigated grass area, it refers to the area with irrigated grass downhill, that will be effective producing grass depending of the water and land availability.

Parents Node: *Available water, Grass area to Irrigate* and *Irrigation efficiency.*
The node Available water was explained already.
Grass area to Irrigate, it reflects the area available to use for grass irrigated, with two states Current and Future.
Irrigation efficiency, it reflects the efficiency of irrigation changes according the technology used, in this case if the sprinkler system is not managed properly the efficiency goes down. This node expresses also one of the activities implemented by PRONAMACHCS.

To fill the CPT the next expression was used:

$$Irrigated\ grass\ area = \frac{Available\ area}{CWR_{grass} \times 10} \times \frac{1}{Irrigation\ efficiency}$$

Where:

Irrigated grass area:	express in hectares
Available water:	express in m^3
CWR_{grass}:	500 mm (Hannaway, 1999).
Irrigation efficiency:	express in percentages.

According the minimum and maximum values from the variables, the states for the node *Irrigated grass area* was fixed. The resulting CPT is shown in the table 4.4.

Table 4. 4 CPT – Irrigated grass area

Available water	Grass area to Irrigate	Efficiency	Irrigated grass area
50000	Current	0.6	6 to 14
50000	Current	0.7	6 to 14
50000	Future	0.6	6 to 14
50000	Future	0.7	6 to 14
300000	Current	0.6	14 to 22
300000	Current	0.7	14 to 22
300000	Future	0.6	14 to 22
300000	Future	0.7	14 to 22
1000000	Current	0.6	22 to 30
1000000	Current	0.7	22 to 30
1000000	Future	0.6	22 to 30
1000000	Future	0.7	22 to 30

4.3 Description of the Bayesian Network

The Bayesian Network built is covering the following aspects:
- It represent the main activities in the watershed,
- It represent the information supplied by PRONAMACHCS,
- The links between activities not only represent the beliefs of the author, is based also in the experience reported by the World Bank, and what they expect from the project, information given for the people working in PRONAMACHCS.

General Characteristics	
Number of nodes	50
Number of Links	66
Total of Conditional Probabilities	803

The Bayesian Network represents the Ayas watershed system described in the chapter 3. The definitions of the nodes, with their respective conditional probability tables are shown in the Annex II.

4.3.1 Software Used

The software used for elaborate, test and use the Bayesian Network is The Netica application from Norsys, version 1.12. Netica Application is a comprehensive tool for working with Bayesian belief networks and decision networks. The figure 4.4 shows how the interface looks like. The links between nodes are showed with arrows, and each node is representing with a box. With the states, and findings gor each one.

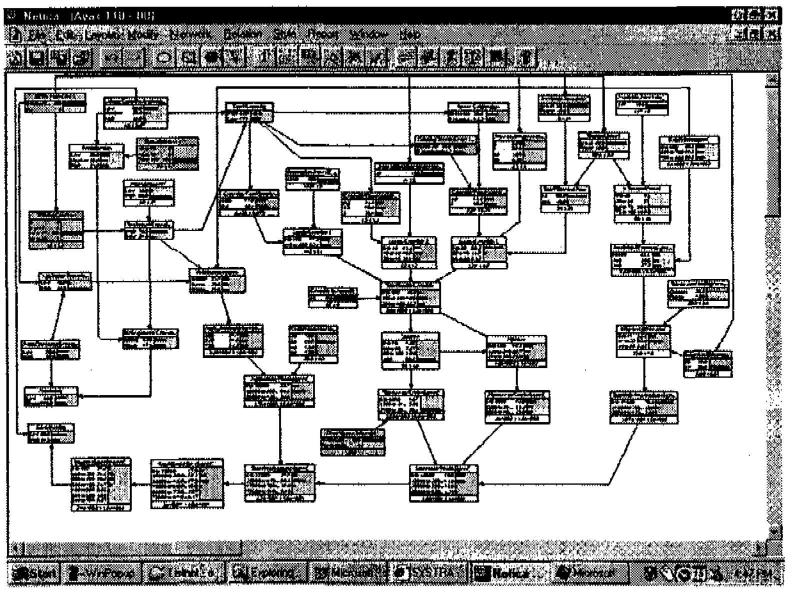


Figure 4. 4. Software used

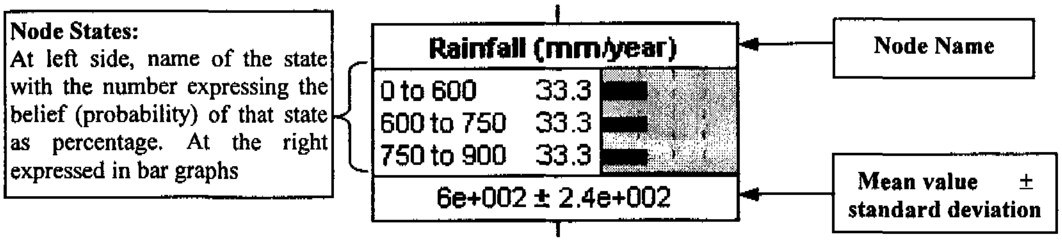


Figure 4. 5 Node format in Netica

4.3.2 Restrictions of the Bayesian Network

Due to lack of data, and complexity in reflecting some ideas, there are some aspects that were not represented by the Bayesian Network, restricting the use of the model

- Sustainability
  The model considers the sustainability according the Project conceptualisation in terms of economic results and participation.
  It will be possible to consider other scales of sustainability, at least in environmental terms, through the monitoring indicators of available land use, and number of animals in production. The negative variation of those indicators will be understood as reduction of available land use, and depletion of the natural resources land and animals.

- Poverty
  The model considers the Income as indicator of Poverty alleviation, as it is considering in the report of evaluation of successful cases. But income level is not only one of the ways to measure poverty; there are another aspects as availability to get education, health, risk and vulnerability (World Bank, 2002).
  At the beginning calories consumption was thinking as indicator of poverty, but there was not enough data to consider it as indicator.

- Markets
  The model do not consider changes in prices because changes in markets of behaviour of the customers. Expressing the prices in US dollars covers changes in prizes due to inflation. The only variation in price considered is the on for vicuna fibre production, because of the mechanism of commercialisation now is restricted because its condition of endangered specie.

- Soil erosion problems
  Soil erosion will reduce the available land to use of the different productive activities, but it was not possible to link the soil erosion control with the available land to use, because there is not a mechanism to link those variables.

4.4 Network Validation

There are not data available to make a validation of the network trough comparison of generated output and field data. The validation referred in this section is more like a test of the model. The model will be tested observing if the watershed system is representing the watershed according the values obtained in field by some nodes.

To "validate" the Network, the value of nodes related to land use, and other known parameters were fixed in order to represent the actual situation of Ayas watershed, and the nodes representing the main outputs objectives were compared to actual project data.

Description of Actual Situation:

- PRONAMACHCS main role: provide agricultural inputs, tools, technical training.
- Suitable actual land use.
- Activities of land management and soil conservation upstream.
- Total Production around U.S.$ 35 000 / year
- Income around U.S.$ 250 / capita / year (from table 3.13)

The node PRONAMACHCS is a kind of switch, to show the influence of PRONAMACHCS in the watershed management.

The following Table summarize the nodes and states used to represent the actual situation to "validate" the Network. This "validation", it is based more in the financial aspect, because of availability of data.

Table 4. 5 Actual Situation represented in the BN

NODES REPRESENTING ACTIVITIES AND CONTROLLING FACTORS				
Title	**Name**	**State**	Finding	Value
PRONAMACHCS	PRONAMACHCS	Intervention No	100% 0	
Beneficiaries (%)	Beneficiaries	10 to 40 40 to 70 70 to 100	0 0 100	85 ± 8.7
Training Courses	Training_Courses	0 0 to 12 12 to 24 24 to 36	0 0 100 0	18 ± 3.5
Treated Area (X1) ha	Protection_AreaX1	13500	0	0
Cultivated_Area	Cultivated_Area (ha)	26 36 46 56	7 85 4 4	36 ± 5.2
Other Similar Infr	Other Similar Infr	14	100	14
Fiber vicuña Price ($/k)	Price_F_V	Restricted Non-restricted	100 0	308
Treated_Area1	Treated_Area	Actual Future	90 10	86.1 ± 9.3
Treated_Area2	Furrow_Area2	Future Actual	10 90	5 ± 14
Area under_grass	Grass Furrows	0 3 10 20	6 92 1.8 0.2	3 ± 1.4
Grass area to Irrigate	Irrig_G_AreaT	Current Future	95.5 4.55	20.5 ± 2.1

There are some nodes that were fixed with 100% of findings, because there is more certainty about the information of then than the others. For instance the node PRONAMACHCS, it is 100% of certainty about its participation.

According FARMOD sheets (Annex I), there were 19 courses since 1999, and then the finding is for sure 100% in training course range 12 to 24.

Table 4. 6 Nodes showing Actual Situation

NODES REPRESENTING OUTPUTS AND OBJECTIVES						
Title	Name	State	With PRONAMACHCS		Without PRONAMACHCS	
			Finding	Value	Finding	Value
lirrigated grass area	Irrig_G_Area	10 to 16	33.3	15.6 ± 4.8	33.3	15.6 ± 4.8
		16 to 22	63.6		63.6	
		22 to 30	3.03		3.03	
Income ($/capita/year)	Income_P	0 to 100	14.2	240 ± 130	20	220 ± 130
		100 to 200	24.2		26	
		200 to 300	29.2		27.7	
		300 to 400	21.7		19.1	
		400 to 500	8.53		5.81	
		500 to 600	1.68		1.1	
		600 to 700	0.37		0.22	
Sustainability	Sustainability	Low	65.5		68.7	
		High	34.5		31.3	
Autonomy	Autonomy	Low	51.5		61.7	
		High	48.5		38.3	
Management Capacity	Manag_Capacity	Strenght	52.5		27.1	
		Weak	47.5		72.9	
Irrigation Efficiency	Efficiency	0.60	10%	0.69 ± 0.049	60%	0.64 ± 0.049
		0.70	90%		40%	

The value obtained for Income is 10 dollars less, 4% of difference, but with a standard deviation of 130 dollars (around 50%). The values of Irrigation efficiency are in the range established. The average of Irrigated grass area is almost 5 hectares less than 20 hectares, 25% of difference.

Although the values are not quite accurate, it is considered representing the system in the physical (land and rainfall) and economical aspect.

The Node *PRONAMACHCS*, works as switch, representing the influence of *PRONAMACHCS* in technical capacity, when the findings for *Irrigation efficiency* go down because no Intervention of *PRONAMACHCS*. Then it can be considered that the managerial aspects in the watershed are quite represented.

The Bayesian Network built it is not the only and unique model to represent the watershed system; it will depend of the people involved in the building process. This Network is subjected to changes and improvements, through additional nodes, changes in the states ranges, or changing the conditional probability tables, based on the same framework.

4.5 Sensitivity Analysis

Before to make an analysis about the watershed management, the characteristics of the Bayesian Network was examined via sensitivity analysis.

Sensitivity analysis was used to identify network components (nodes) that have the greatest influence on the outcomes of interest; namely:

- *Income per capita*
- *Sustainability*
- *Autonomy*
- *Management Capacity*

Sensitivity analysis was conducted by systematically varying the state of some nodes of the network to determine effects on the outcomes of interest.

The selected nodes were:
- *Attendance (%) = Attendance1*: Attendance of the courses implemented by PRONAMACHCS
- *Beneficiaries (%) = Beneficiaries*: Percentage of the people benefited by the Project
- *Cultivated Area = Cultivated_Area*: Area used by agriculture
- *Irrigated grass area = Irrig_G_Area*: Grassland for cows
- *Labour Contribution = Labor_Contribution*: days/week, campesinos work in activities related to watershed management.
- *PRONAMACHCS = PRONAMACHCS*: switch
- *Rainfall = Rainfall*: annual average rainfall in mm
- *Total Treated Area 1 = Total_FI_Area*: Total Area with furrow infiltration
- *Total South Camelids = Total_S_C*: Total number of camelids that can support the land
- *Yield Improvement = Yield_Improve*: Expectation of changes in the yield

The analysis was made in the scenarios defined in the table 4.7

Table 4. 7 Definition of Scenarios

Variables	Sc1	Sc2	Sc3	Sc4
Appropriate Land Use	Actual	Actual	Future	Future
PRONAMACHCS	Intervention	Non-Intervention	Intervention	Non-intervention

- Appropriate Land use: According the actual appropriate land use, it was fixed according the table of effective actual land use, chapter 2, table 3.13.
- PRONAMACHCS: The main activities are link to Agricultural Inputs, and Technical Training.

Netica provides a useful tool for sensitivity analysis, providing the values of the variables and the respective parameters of measure like quadratic score.

Table 4. 8 Summary of the Sensitivity Analysis

Scenary	Income	Sustainability	Autonomy	Manag Capacity
1	Yield_Improve Irrig_G_Area Rainfall Cultivated_Area	Yield_Improve Irrig_G_Area Rainfall Labor_Contribution	Labor_Contribution Yield_Improve Beneficiaries Total_S_C	Labor_Contribution Beneficiaries Total_S_C Yield_Improve
2	Yield_Improve Irrig_G_Area Rainfall Cultivated_Area	Yield_Improve Irrig_G_Area Labor_Contribution Rainfall	Yield_Improve Labor_Contribution Beneficiaries Total_S_C	Labor_Contribution Beneficiaries Total_S_C Yield_Improve
3	Rainfall Irrig_G_Area Yield_Improve Cultivated_Area	Rainfall Irrig_G_Area Yield_Improve Labor_Contribution	Labor_Contribution Yield_Improve Beneficiaries Total_S_C	Labor_Contribution Beneficiaries Total_S_C Yield_Improve
4	Rainfall Irrig_G_Area Yield_Improve Cultivated_Area	Rainfall Irrig_G_Area Yield_Improve Labor_Contribution	Yield_Improve Labor_Contribution Beneficiaries Total_S_C	Labor_Contribution Beneficiaries Total_S_C Yield_Improve

From Analysis Sensitivity it is possible to identify which nodes have more influence in the variations of the interested outcomes. Following the table 4.8 shows a summary of the first 4 nodes with more influence in each case, in the annex III, a more detailed table is shown, and also graphically results.

Analysis for each Outcome is presented below:

Income
In the first two scenarios the amount of land used for the different activities remains constant, for that situation Income is affected more for the *Yield Improvement* than for *rainfall* or even *Irrigated grass area*. In the 3rd and 4th scenarios, because an increase in the amount of land used, Income is more dependant by *rainfall* than the other outcomes.

Sustainability
Sustainability is directly related with *Income* and *Labour contribution*, effectively in the 1st and 2nd scenarios is affected by the same variable that *Income*, it means by *Yield Improvement*, but instead of be influenced by *Cultivated area*, is influenced by *Labour contribution*.
In the 3rd and 4th scenarios, Sustainability is more dependent by *rainfall* than *Irrigated grass area, Yield Improvement* or *Labour contribution*, in that order.

Autonomy
Autonomy is directly related with *Labour contribution* and *Yield Improvement*; in the 1st and 3rd scenarios *Labour Contribution* has more influence than *Yield Improvement*, because of PRONAMACHCS intervention. In the 2nd and 4th scenarios Yield Improvement has more influence than Labour Contribution, because without PRONAMACHCS, it will be necessary to increase the productivity to become autonomous.

Management Capacity
In the four scenarios the variables chosen have the same influence, in the same order. The variations of land do not affect this variable, neither the intervention of PRONAMACHCS. In the tables of Annex III, it can be observed attendance gets some influence in the 1st and 3rd scenarios.

4.6 Uncertainties

As has already been mentioned, uncertainties are implies in all the activities of watershed management like rainfall.
The degree of uncertainty depends on the confidence in the data and the information obtained.

Principle sources of uncertainty include:

- The boundaries of Ayas watershed are not fixed. A boundary was assuming using the plans of the soil study report. The determination of the area that infiltrates water to the spring: Quinualpuquio was based in this assumption as well the amount of area for the different land uses.
- The quantity of vicunas is variable, because they are wild, not captive, species. When campesinos make the shearing sometime do not capture all the vicunas, or not the same number, then the fibre production captures this uncertainty.
- There are not records of discharges in the spring, only reference data. Based on this data infiltration rates were assumed.
- The expansion in the land use, for instance to extend area under grass or Cultivated area, have a high uncertainty, because there is not information neither reports about the growing rate, or capacity to face an increment in the areas.
- The rate infiltration or only the infiltration process in karstic has high uncertainty, because is not a well-known phenomenon.

5 Watershed Management Analysis using the BN

Having built the Bayesian Network and knowing the Ayas watershed system; it is possible to do an analysis of the watershed management using the Bayesian Network built with two purposes:

- Get a better understanding about Ayas watershed management, to define the actual situation of the watershed management, and how the strategies in the watershed management can be redefined in order to achieve the objectives or maintain the results reached.

- Use the Bayesian Network for the analysis, and evaluate its usefulness in Watershed Management and how it can be used as decision support system tool.

Analysis focuses on the behaviour of the variables: Income, sustainability, Autonomy and Management Capacity. These variables are the indicators chosen to evaluate the achievement of the project objectives:

- Poverty alleviation through sustainable management of natural resources through soil conservation measures like the furrow infiltration areas. With the variable: *sustainability.*
- Increase rural production and productivity through improved agricultural practices. With the variables: *Sustainability* and *management capacity.*
- Strengthening the Managerial Capacity of Community Organisations so that they can become autonomous. With the variables: *Autonomy* and *Management Capacity.*

The analysis will also study how the physical and non-physical variables respond in the system.

The analysis was done changing the different states of specific nodes, in order to define the scenario of analysis. After the scenario was established, an evaluation of changes in the findings nodes of interest was done. The Bayesian Network used for the analysis is the one shown in the figure 4.3.

In annex IV, a compilation of the Bayesian Network used, with the different states established, is shown. The structure and information filled in the Bayesian Network do not change, and the links, and the conditional Probabilities remain the same: only change the states.

The scenarios of analysis are defined in base on two facts:

- How will be the responses of the watershed system if PRONAMACHCS is not implementing any project in the watershed? And
- How will be the responses of the watershed system if the actual land use increases?

It was not possible to analyse the effectiveness of the watershed management comparing the actual situation with a previous one before the Project Implementation, because there is no data available to make the analysis using the Bayesian Network. The data available about the previous and actual situation is very general, but can give us some level of understanding about the effectiveness of the strategies implemented, the description of the Actual Situation is presented before the Watershed Management Analysis.

5.1 Actual Situation of Ayas Watershed Management

According PRONAMACHCS – Tarma (2002) and PRONAMACHCS (2002), the actual watershed management under the scope of Poverty alleviation Project improve related to the previous situation.

According those reports some of the problems identified in the previous situation are:
- Deficient management and exploitation of water resources and soil.
- Scarcity of soil suitable for crop.
- Intensive erosion processes.
- ***Low production and productivity.***
- Extreme changes in the prices of the products.
- Intensive cropping in the soils with mono-cropping.
- High use of chemical fertilizer and pesticides.
- Many Institutions working without coordination.
- Low educational and technical level of the producers.
- Paternalist and conformist behaviour of the people.

With the Implementation of the project they report some achievements like:
- Annual per capita income with project: U.S. $ 250, without project: U.S.$ 110, table 3.3
- Significant increase in yield grass (PRONAMACHCS – Tarma, 2002).
- Increase in the crop yields and in milk Productivity (PRONAMACHCS – Tarma, 2002).

These results indicate a level of success in the achievement of poverty reduction, and increase of productivity. The increase in the productivity is because they implement a new productive activity through milk production. The increase in yield production is another factor that influences the increase in productivity. But about the other productivity activity: vicuna fibre and alpaca fibre it is not mentioned anything.

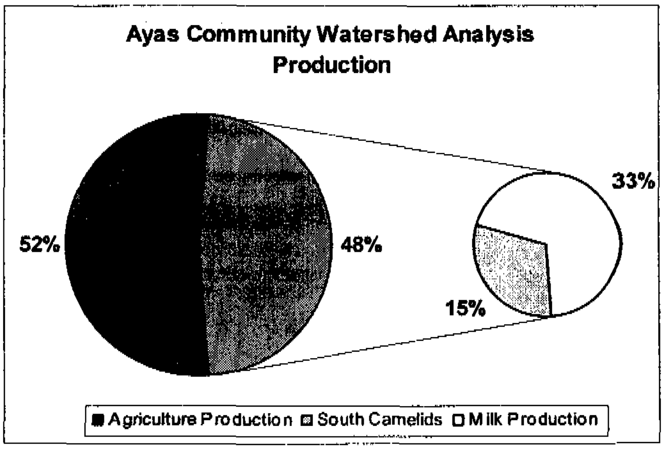


Figure 5. 1 Productivity activities

From the Bayesian Network shown in figure 4.3, the figure 5.1 similar to the figure 3.1 was elaborate. From the comparison of those figures it can be identified there are no big differences in the percentages of each activity. The total production value obtained from the model is around **32,000 US. $/year**, close to **35,000 U.S.$/year** from table 3.3

About the activities, agriculture the first one, depends on rainfall, cultivated area, and agriculture productivity; it relies on agriculture inputs and water availability.

The second one is milk production. This activity depends of the irrigated grass area, irrigation system and water availability.

The third one is the commercialisation of vicuna fibre and alpaca fibre. This activity is more dependent of the capacity food supply or supportability of the land and markets.
All these activities require of Technical Capacity and some of them are so heavily dependent on PRONAMACHCS like provision of Agriculture Inputs. That is why the Autonomy is Low. There is not enough participation and with the low Income, it is considered not to be sufficiently sustainable.

5.2 Responses of the Watershed System to Income, Sustainability, Autonomy and Capacity Management

In this first stage, the responses of the variables *Income*, *Sustainability*, *Autonomy* and *Capacity Management* are analysed in four scenarios established, as it is shown in the Table 5.1

Table 5. 1 Scenarios for Analysis in the Stage 1

Variables	Sc1	Sc2	Sc3	Sc4
Appropriate Land Use	Actual	Actual	Future	Future
PRONAMACHCS	Intervention	Non- Intervention	Intervention	Non-intervention

After running the Bayesian Network in the four scenarios defined, the results of the variables are shown graphically in the figure 5.2 The Bayesian Network with the respective states defined for the four scenarios is shown in the Annex IV.

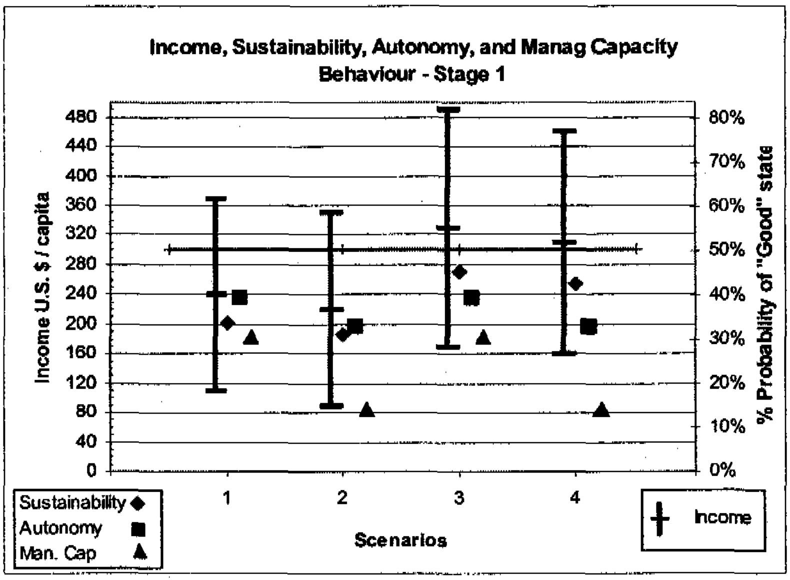


Figure 5. 2. Income, Sustainability, Autonomy and Management Capacity

In the figure 5.2, the horizontal line is a sort of POVERTY LINE, for rural sierra areas in Peru, poor is defined when the consumption is less than **300 U.S. $/capita/year** (Francke, no date).

It can be observed that only when the available land for furrow infiltration and irrigated grass is used, even with or without PRONAMACHCS intervention, the Income increase in more than **80 U.S.$/capita/year**, and could pass over the poverty line.

Actually the Income/capita/year is around **250 U.S. $,** this is quiet well represented in scenario 1 with a value of **240 ± 130 U.S. $**. But if at this moment PRONAMACHCS leaves the watershed, there will be a decrease in *Income*, due to decrease in nodes linked directly with PRONAMACHCS like *Ag. Inputs Provision* (related with *Yield_Improve*).

Sustainability and *Autonomy* do not have a dramatic change like *Management Capacity* when PRONAMACHCS is not anymore working in the watershed. *Management Capacity* depends of Participation and Technical Capacity; the last one is a main activity of PRONAMACHCS.

From the four scenarios, the increase of the areas for furrow infiltration and grassland will increase the Income, but the other outcomes remain with low values.

How we can get higher values of *Sustainability*, *Autonomy* and *Management Capacity*?
Using the Bayesian Network, we can select the high states for *Sustainability*, *Autonomy* and *Management Capacity* and analyse how the other nodes change their findings.

But from the 47 nodes, which ones are going to be analysed?
First, *Income* the other outcome of interest is analysed. Then, from the sensitivity analysis in chapter 4, the nodes with more influence in the outcomes of interest identified will be the ones to analyse. The description of the analysis is presented below.

5.2.1 Autonomy, Management Capacity and Sustainability Maximum

In this second stage the system response for conditions defined in the Table 5.2, is analysed.

The Bayesian Network with the high states fixed for *Sustainability*, *Autonomy* and *Management Capacity* in those different conditions are shown in the Annex IV.

Table 5. 2 Scenarios for Analysis in the Stage 2

Variables	Sc1	Sc2	Sc3	Sc4
Appropriate Land Use	Actual	Actual	Future	Future
PRONAMACHCS	Intervention	Non- Intervention	Intervention	Non-intervention
Autonomy	Enough	Enough	Enough	Enough
Management Capacity	Strong	Strong	Strong	Strong
Sustainability	High	High	High	High

How response the Income?

The figure 5.3 shows the behaviour of the Income in the four scenarios for the previous and current stage.

When the non – monetary outcomes are in their highest state, there is an increase in the Income related to the previous one in stage 1, in more than **50 U.S. $** in scenarios 1 and 2, and more than **60 U.S.$** in scenarios 2 and 3.

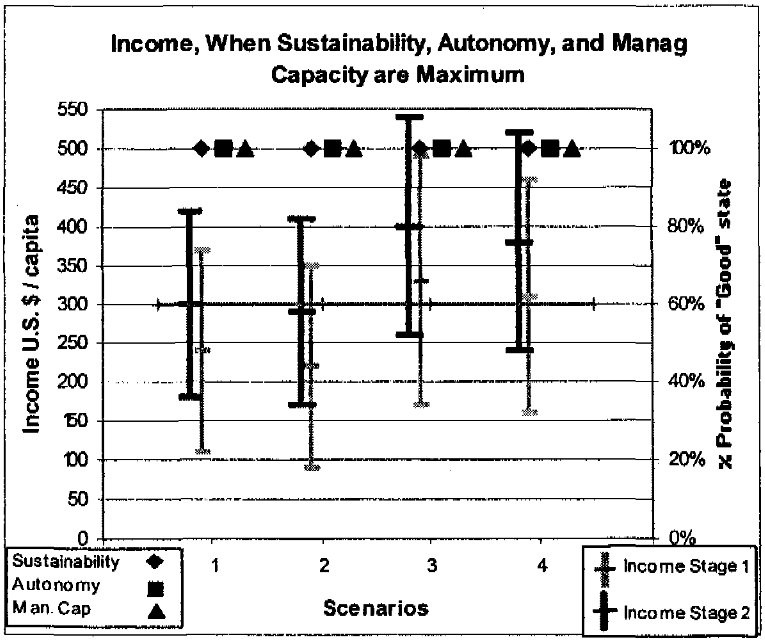


Figure 5. 3 Changes in the Income for High States of non-monetary Outcomes

Similar to the previous analysis – Stage 1 – the fact of increasing the land area for furrows infiltration and irrigated *grass* will increase the Income in **100 U.S. $/capita/year**, with presence of PRONAMACHCS, and in almost **80 U.S. $/capita/year**, without the presence of PRONAMACHCS. The presence of PRONAMACHCS also has influence in Income increase, but lower than the land increase.
From this figure the importance of the other non-monetary outcomes related to the increasing in the Income is clearer. To increase the Income is not only a matter of land increase is also related to the other non-monetary outcomes.

Let us concentrate now on an increase in the areas for furrow infiltration, in order to get higher Incomes. The actual land used for furrow infiltration is 83 hectares, and the available land for this activity is 160 hectares, there is a difference of 77 hectares that will require investments to be implemented.

The investments for soil conservation activities as it is shown in FARMOD sheets (Annex I), cover expenditures in tools, labour and PRONAMACHCS technical assistance. Considering only the investments to cover tools and technical assistance, a rough estimation of the required investment is presented in table 5.3

Table 5. 3 Cost Investment for Soil Conservation Structure

Type of Structure	Tools U.S. $/ha	Technical Assistance U.S. $/year
Furrow Infiltration	85	840
Slow formation Terrace	95	840
Absorption terrace	325	840

Source: FARMOD

To increase the areas of furrow infiltration at the maximum, and assuming the work will be done in one year, the Investments required are shown in the Table 5.4

Table 5. 4 Investments to expand Furrow Infiltration area

Tools (U.S. $)	Technical Assistance (U.S.$)	TOTAL (U.S. $)	TOTAL (U.S.$/capita)
77 x 84 = 6545	840	7385	7385 / 122 = **60**
77 x 84 = 6545	0	6545	6545 / 122 = **54**

From the analysis of figure 5.3, the changes of Income due to land increase are in the order of **80 US $/capita**, whether in the stage 1 or 2. This increase would be possible if there is an investment in furrow infiltration of around **60 U.S.$/capita**. Looks like, the investments will be recovered, but this are referential numbers, do not forget that there is a range of more than **100 U.S.$** of uncertainty.

How response the non – monetary outcomes?

From the tables of Sensitivity Analysis - Annex III it can be identified 3 common variables than have some influence in *Sustainability*, *Autonomy* and *Management Capacity*.

The variables are:
- *Yield_Improvement*
- *Labour Contribution and*
- *Total_S_C*

One variable that was also considered is *Auto financing Capacity*, because its heavily influence on *Yield improvement.*

The following figure shows how these 4 variables change their findings in the four scenarios, for the previous stage – Stage 1 – and for this stage – Stage 2 –.

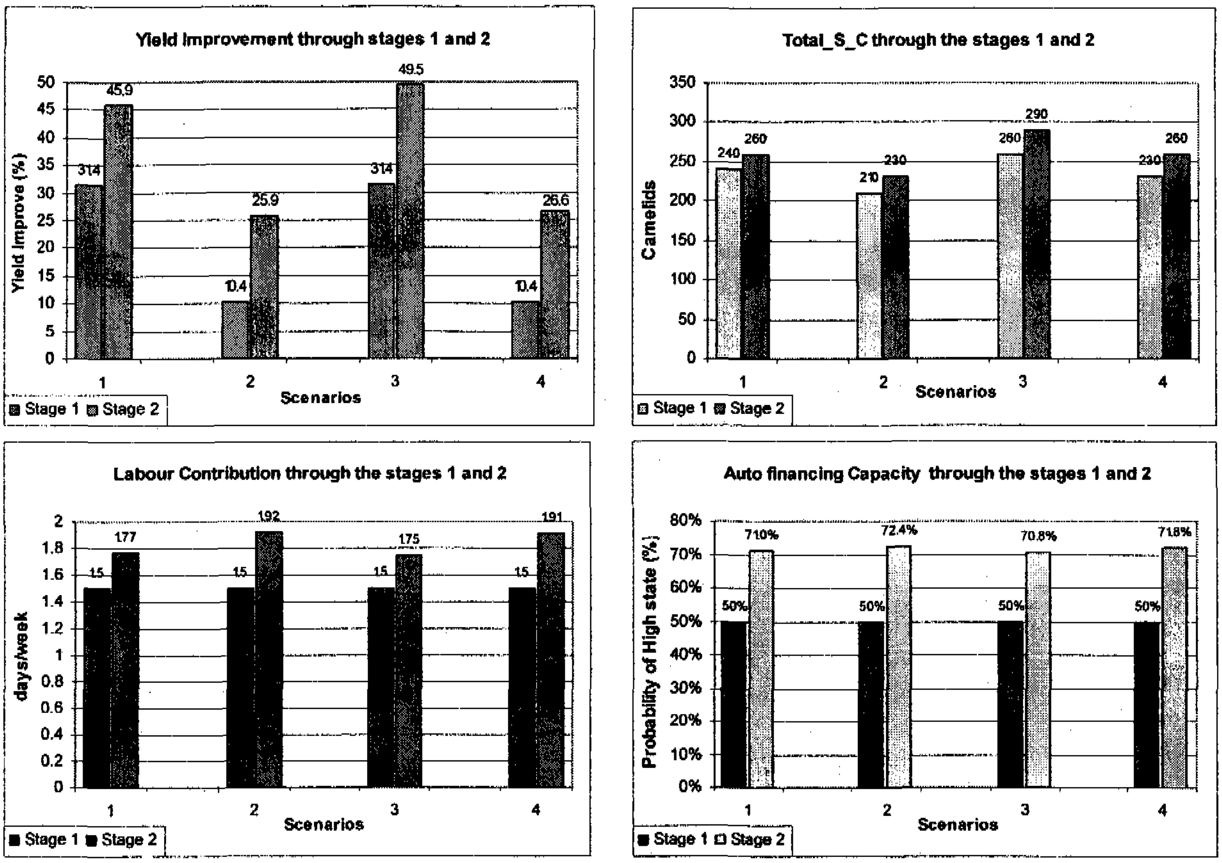


Figure 5. 4. Non-monetary outcomes change in the four scenarios through stages 1 and 2.

Yield Improvement

The probabilities of improve the yield increase respect to the stage 1 in more than 14%, whatever PRONAMACHCS intervention. The probabilities of improve *yield* are low when PRONAMACHCS is not anymore in the watershed, because there will not be more provision of agriculture inputs by PRONAMACHCS, neither technical capacity.

For the stage 2, when *Sustainability*, *Autonomy* and *Management Capacity* are high, the probabilities of Improve the yield ranges from 25% to 50% (figure 5.4), and the probabilities of get the same yield ranges from 29% to 32% (Bayesian Networks Annex III), even PRONAMACHCS is not in the watershed the probabilities of diminish the yield is less than 50%, respect to the present situation.

Total South Camelids

In the two stages, there is increase in the total number, when there is more land available, but when PRONAMACHCS it is not more in the watershed, the increase is not so high, because there is lack in the land management, and in land supportability.

The variation in the total number between stages 1 and 2, in whatever or the 4 scenarios is around 20 and 30, more or less 10% of the total.

Labour Contribution

The maximum value we can get in Labour Contribution is 3 days/week. In the watershed the value is quiet low 1.5 days/week in the first stage and a range between 1.7 to 1.9 days/week in the second stage. For the stage 2 the values vary in function PRONAMACHCS intervention. More labour contribution will be required if PRONAMACHCS is not more in the watershed.

Auto financing Capacity
Auto financing capacity is constant in the different four scenarios, but when the non-monetary outcomes are in their high state, it is necessary a high financing capacity to provide the agricultural inputs, and increase the Autonomy.

From the analysis, the variables that show more changes because of *Sustainability*, *Autonomy* and *Management Capacity* are *Yield Improvement* and *Autofinancing Capacity*.

Then, in order to improve, *Sustainability*, *Autonomy* and *Management Capacity*, so much effort has to focus in the increase of *Yield Improvement* and *Autofinancing Capacity*.

Then what are the activities and variables that affect those nodes?
Yield Improvement

- *Rainfall* is a control variable, is not possible to manage, only improve water harvesting practices.
- The *Technical Capacity*, without PRONAMACHCS it will be difficult to get high Technical Capacity. Then it is necessary that PRONAMACHCS train effectively the community, and implement a mechanism of periodical technical training to the Community.

The *Auto financing capacity* influences *Yield Improvement* through provision of agriculture inputs. A high *Auto financing capacity* will depends of Income, but this link is not show in the Bayesian Network because will generate a loop that the system can no stand. High *Auto financing capacity* will permit provision of agriculture inputs to the watershed; give Autonomy to the community and support technical training in absence of PRONAMACHCS.
At present conditions the watershed system is heavily dependent of PRONAMACHCS, all the conditions referred above are not given, then the system is not enough sustainable neither Autonomous.

We only analyse the non-monetary outcomes in their maximum states. But how about the Income, how much we can increase the Income in this watershed system?
Following the analysis of the watershed when the Income is at the maximum state.

5.2.2 What happen if only the Income is Maximum?

Fixing the maximum stage of the Income, an analysis of the watershed system responses in the different four scenarios (table 5.5.) is presented below. The Bayesian Network with the high state fixed for *Income* in those different conditions are shown in the Annex IV.

Table 5. 5 Scenarios for Analysis when only Income is Maximum

Variables	**Sc1**	**Sc2**	**Sc3**	**Sc4**
Appropriate Land Use	Actual	Actual	Future	Future
PRONAMACHCS	Intervention	Non-Intervention	Intervention	Non-intervention
Income	650 +- 29	650 +- 29	650 +- 29	650 +- 29

The maximum ranges of income established in the node *Income* ($/capita/year) are based on the productivity activities of the system. The maximum ranges in Income are related with the maximum range of Total Benefits, and the last one with Total Production, and in the same way the previous nodes linked to this.

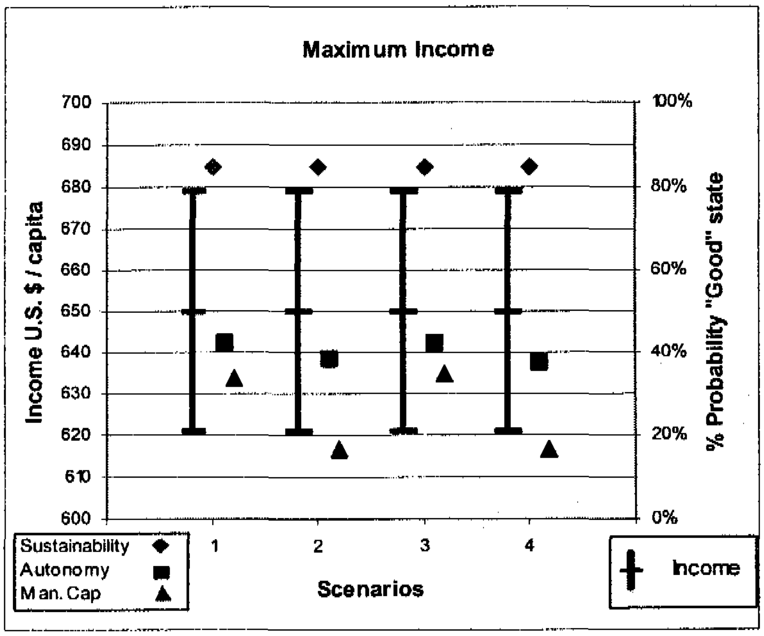


Figure 5. 5 Non – monetary outcomes when Income is Maximum

From the results of the Bayesian Network, the figure 5.5 shows a summary of the behaviour of the non-monetary outcomes in the four scenarios.

Sustainability will reach high values, more than 80% in the four scenarios; it is expected because the direct link between Income and sustainability. Management Capacity always reaches low values when PRONAMACHCS is not in the scenario. Autonomy even high capacity do not reach values bigger than 40%, this is a restriction in the model because it was not possible to linked with Income.

How about the other variables in the system?

Rainfall

We can observe in the Bayesian Network with the respective states for the different four scenarios (annex IV), the node that changes their findings more drastically compared with the other nodes is rainfall.

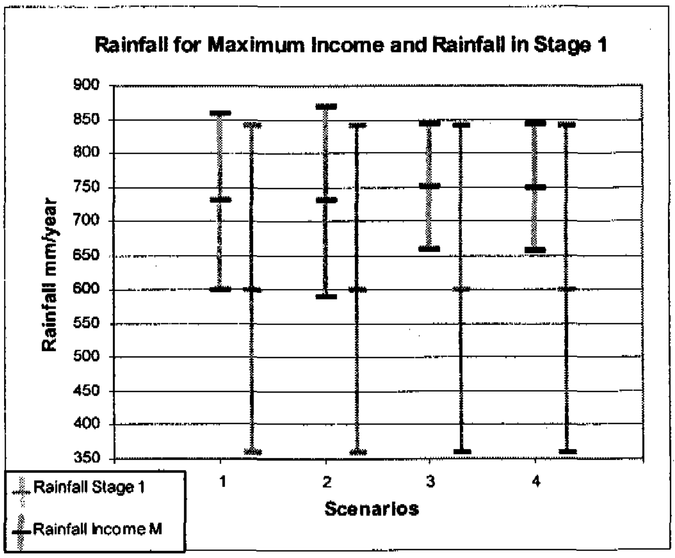


Figure 5. 6 Rainfall in stage 1 and when Income is maxim

The figure 5.6 shows the rainfall behaviour in the stage 1, and when the Income is maxim. The average values of rainfall related with the maximum Income are in the range from 730 to 750 mm/year. If we compare these values with the values of rainfall in the stage 1 (light lines), the average is around 600 mm/year. High rainfall will produce high Income.

Depending only from the rainfall, to get a maximum Income, the system only have to wait for a good wet season, that according the table 3.13 has a probability of occurrence around 30%.

Then, to improve the income a good strategy combining a good land use and increase in the area of furrow infiltration have to be implemented, or maybe wait for a good wet season! Again improve the water harvesting activities with the soil erosion control structures will provide enough water for the agriculture and grassland production.

5.2.3 What happened if all the outcomes are in their highest positive state?

In this third stage the system response for conditions defined in the Table 5.6, is analysed.
The Bayesian Network with the high states fixed for *Sustainability*, *Autonomy*, *Management Capacity* and *Income* in those different conditions are shown in the Annex IV.

Table 5. 6 Scenarios for analysis in the Stage 3

Variables	Sc1	Sc2	Sc3	Sc4
Appropriate Land Use	Actual	Actual	Future	Future
PRONAMACHCS	Intervention	Non- Intervention	Intervention	Non-intervention
Autonomy	Enough	Enough	Enough	Enough
Management Capacity	Strong	Strong	Strong	Strong
Sustainability	High	High	High	High
Income	650 +- 29	650 +- 29	650 +- 29	650 +- 29

From the analysis in Stage 2, the nodes that are more influenced by *Sustainability*, *Autonomy*, and *Management Capacity* are already identified:

- *Yield_Improvement*
- *Labour Contribution and*
- *Total_S_C*
- *Auto financing capacity*

In case of Income the analysis of rainfall variation was already done, lets focus now on the variations of the 4 variables identified. The figure 5.7 shows the variation of the variables trough the 3 stages.

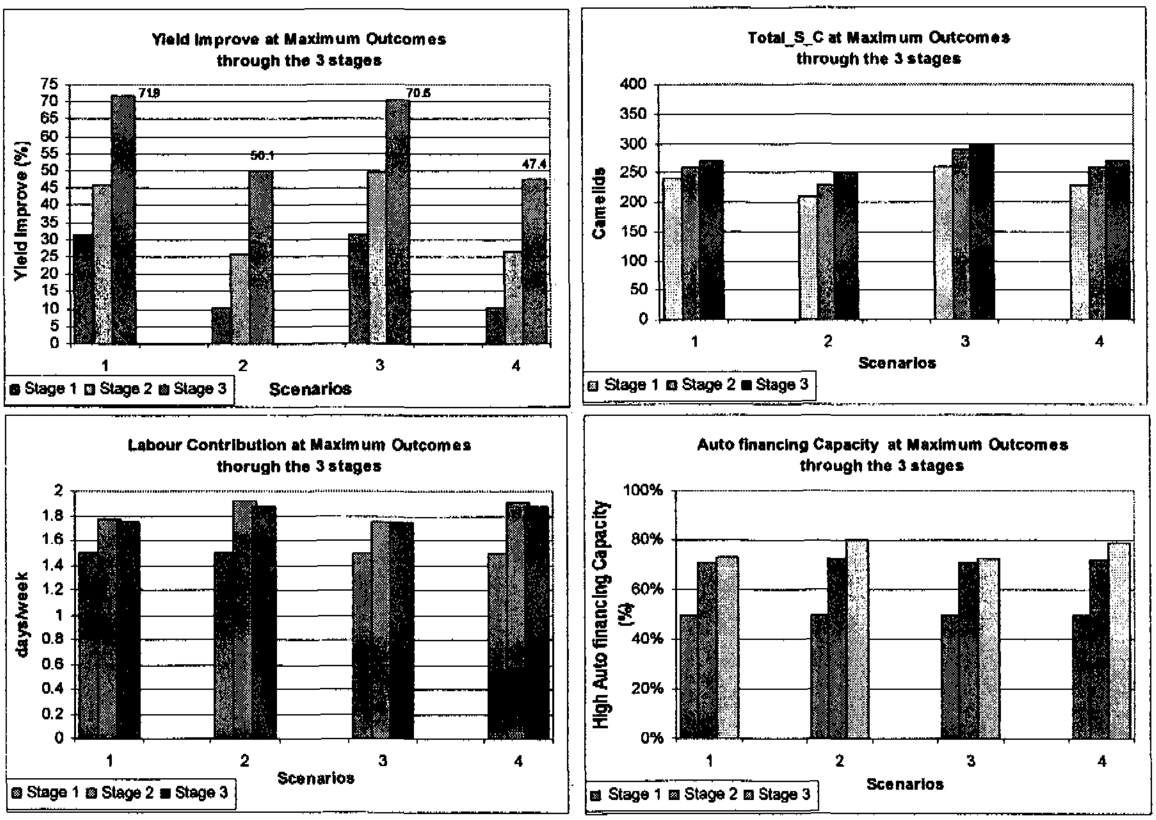


Figure 5. 7 Variations in Yield Improve, Total_S_C, Labor Contribution and Auto financing Capacity for the three different stages.

From the figure 5.7 it can be observed that:

- All the variables with exception of *Labour Contribution* have the same ascending pattern through the three stages. Why is this happening?
  Analysing the links that part from *Labour Contribution. Labour Contribution* link to *sustainability, participation*, and *Total Capacity.*
  Sustainability is more depending of *Income* than of *Labour Contribution.* Then when *Income* is high, it is not necessary high levels of *Labour Contribution* to get high levels of sustainability. Then comparing the values of stage 3 with the values of stage 2, where Income was not at its maximum value, in order to get high sustainability the Labour Contribution fill the gap of the Income. If you have enough money you will hire somebody else to do the work.
- It is required highest values of Yield Improve in order to reach highest Incomes, because agriculture represents the 52% of the Total Production.
- Auto financing is always required to be high, because this lead into a high autonomy, agriculture input provision, and consequently improve the yield and increase agriculture production.

5.3 Results from the Analysis

After the analysis, the results are summarize as follow:

5.3.1 Actual Situation

Agriculture is the main productive activity in the watershed, followed by milk production and south camelids fibre production.

A permanent technical capacity is required to sustain the actual system, because the three productive activities mentioned are based on a certain level of improved technical capacity since:
- Milk production is based on grass irrigated by a sprinkler system, and land management with seeding grass and fencing to protect the growing grass.
- The fibre vicunas and alpacas production is based on native grass seeded in furrow infiltration areas with fencing to protect the growing native grass.
- Agriculture production, based on utilisation of selected seeds, fertilizers and sometimes pesticides.

The fibre production of vicuna would deserve more attention from the Community, because since this activity is based on a protected wild animal: vicuna, there is a legal framework for its commercialisation favourable to the campesinos. According law Campesinos Communities are the only ones allowed to commercialise vicuna fibre. The community have to take advantage of this fact, and develop more this productive activity. At present looks like PRONAMACHCS does not deserve the attention expected to this activity, there are few references about the fibre production in the reports and studies.

The main activities of PRONAMACHCS are Technical Capacity, provision of Agricultural Inputs and facilitation of soil erosion control structures. The fencing and manipulation of the sprinkler system it is now in charge of the community, looks like they could manage that by themselves without problems.

At present the watershed system:

- Do not have enough Autonomy; it is still depending of PRONAMACHCS, the management capacity is still low.
- The level of Income is still under the poverty line.
- It is not enough sustainability due to low participation and low Income.

5.3.2 Responses of the Watershed System to changes in Income, Sustainability, Autonomy, and Management Capacity

Income

Increasing the land used for furrow infiltration and irrigated grass will produce direct increments in the Income level, the maximum levels of Income will be reached if there is enough rainfed water. Income is very dependent of rainfall, more than the area of land used for the productive activities. Then improvement of the water harvesting activities with the soil erosion control structures is a key activity in the watershed management in order to increase the Income level.

Sustainability, Autonomy and Management Capacity

Labour contribution is an important variable to get high Sustainability when the Income levels are low, but it is less important when the Income levels are high.
Autonomy will be reached if the Community raise high Auto financing capacity. The Auto financing capacity will permit provision of agriculture inputs to the watershed and support technical training in absence of PRONAMACHCS.
Management Capacity is heavily related with PRONAMACHCS, and to manage the system is required certain level of technical capacity, and then it is necessary permanent training.

To summarize, a good combination of structural and non-structural measures will improve the watershed management in order to achieve the objectives.

5.3.3 The constraints

The results of the analysis have some limitations due to the constraints in the model that are described below

- There is very much uncertainty about the non-monetary management variables, like Management Capacity or Total capacity, the links are based only in the author believes. The weight given to the non-monetary variables respect the Income is quiet low.

- There is not a direct link between the Auto financing capacity and Income, because will generate a loop that the system can no stand. To solve this weakness in the model, the implementation of a complete second Network as it shown in the figure 5.8 was thinking, but the idea was left because it was more complex.

- The model give a better understanding about the variables involved, what are the tendencies and the relationship among them. The values showed have to be taken like estimations that give an idea about the range of the value.

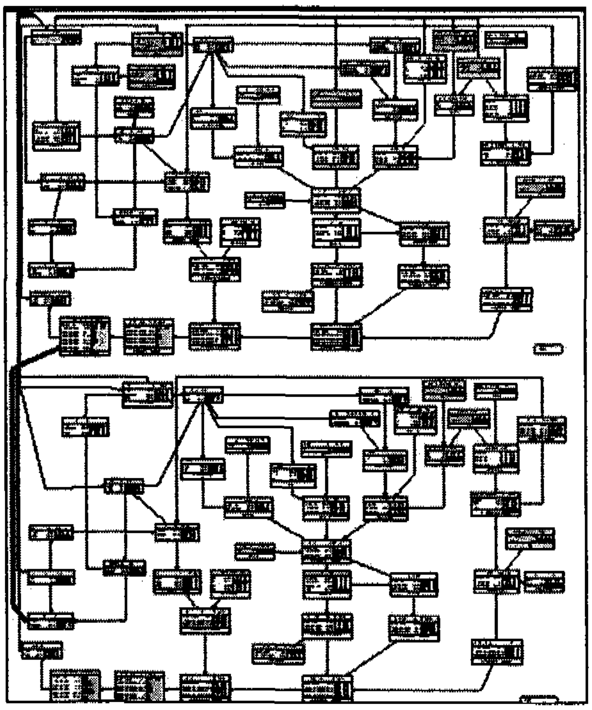


Figure 5. 8 Double Bayesian Network

5.4 Suggestions to Implement in the actual strategies

Based on the analysis of Ayas watershed system using the Bayesian Network, some recommendations are suggested with the aim of improve the actual situation in order to achieve the Project objectives.

- The lands have to be used according its potentialities, based on an elaborated plan of land management and use considering the limitations of labour availability. To achieve this, it is necessary a revaluation of land use, starting with the establishment of the boundaries of Ayas Community, soil studies, census of population willingness to work.

- In the strategies related to Soil conservation Structures
  Implement a plan for maintenance of the actual soil conservation structures; promote the fencing activities and cultivation of native grass in the areas of furrow infiltration.

- In the strategies related to Agriculture Improvement Practices
  Combine the Soil Structure maintenance with water harvesting practices as it is made with furrow infiltration.
  Maintenance and Operation of the sprinkler system have to be supported by special mechanism, in order to support any fail in the system, as well put more attention in the irrigation efficiency.
  About the provision of Agriculture Inputs, look for another alternative mechanism of provision, an autonomous one, and replace this activity with other ways to incentive free Labour Contribution.

- In the strategies related to Reforestation and agro forestry.
  Promote reforestation of uphill areas with native species to control soil erosion and improve land supportability in favour of vicuna fibre production.

- In the strategies related to Strengthening of Community Organisations
  Make an evaluation of the actual technical capacity of campesinos to maintain or improve the actual strategies of PRONAMACHCS in training capacity.
  Realize a Study about the labour contribution in order to implement a program of Incentives and promotions. Looking for a mechanism based more in promotions or legal incentives, than incentives through food provision or agriculture inputs, avoiding programs that create dependency.

- Give more attendance to fibre production activities, taking advantages of the rights in commercialisation, complementing it with soil erosion activities.

- Put attention about the drinking water provision to the community, why it is not in the scope of the watershed management, establish a mechanism of coordination with the institution that provides the service.

5.5 Conclusions and Recommendations

Conclusions

- PRONAMACHCS intervention has high influence in the improvement of managerial variables.

- The system is very dependent of rainfall, then water – harvesting activities have to be implemented in combination with the soil erosion control activities.

- After the analysis of Ayas community case, the main factor that can have a very strong impact, independent of the land managed, is the precipitation.

- Bayesian Network is a very suitable tool to analyze and understand the activities involved in watershed management with many uncertainties, with a poor system of monitoring and data collection.

- Bayesian Network Effectively provide a framework for data collection and analyses, in Ayas Community case, the characteristics of land use, have to be defined better, as well the indicators of participation and effectiveness in the Management Strengthening activity like number of training courses, and attendance to this courses.

Recommendations

- Implement a systematic monitoring system, including not only indicators of activity, also indicators of impact. Promote it use in evaluation of the watershed system, and effectiveness of the project, and PRONAMACHCS activities.
- From the Watershed analysis using the Bayesian Network, the need of activity indicators for the management variables was identified, then is necessary consider indicators like: attendance to training Courses, willingness to participate in training and in the watershed management activities.
- An evaluation of the actual technical capacity of campesinos is required in order to evaluate the effectiveness of PRONAMACHCS activities in Technical assistance, in order to improve or maintain the strategies of this activity.
- Verify and evaluate efficiency in the use of sprinkler system, through capacity of maintenance and operation.
- Implement a more independent strategy for the provision of agriculture inputs.

6 Evaluation of the Use of BN in Watershed Management

How we can measure or evaluate the usefulness of a tool?

Well after using the tool, we can say if we like it or not. Particularly I enjoyed using the Bayesian Network, more than building it. Other way is through comparison with another one used for the same purposes. In this case there was not used another tool to make the evaluation through comparison. Then the evaluation is based only in the appreciations about the use of the tool.

But, to make the evaluation we have to establish parameters not so subjective. Based in the advantages and disadvantages presented in the chapter two, the following "parameters" were established to make the evaluation.

- Versatile
  Once the Bayesian Network is build, it is possible change it according new conditions or new activities involved trough addition or remove of links and nodes, through changes in the condition probability tables.
  In the analysis process the changes in the state of the variables are easy to do and appreciate how the system response.
- Friendly Interface
  The graphical presentation facilitates the identification of changes in the variables in different scenarios.
  The use of Bayesian Networks makes easy to get a better understanding of the system, than reading many reports, or big tables with very small numbers.
  The graphical presentation provides a better understanding about the relationships between non – physical and physical variables for instance land management and active productivity.
- Time consuming
  Build the Bayesian Network only by one specialist that does not have a broad idea about what is going on the watershed, is a time consuming activity.
  Filling the conditional probability table is a time consuming process, depending of the source of data, for instance consultation to specialist, and elaboration of survey are the most time consuming. If the watershed analysed does not have a monitoring system, it will take more time to find information in different reports.

  For the analysis is very easy to make changes and identify variables more affected, anyway it is necessary make graphical summaries like the ones presented.

- Costs
  The software used for Bayesian Network is not expensive, in fact Netica Application cost 248 U.S.$
  The Costs of use are implied in the information needed to fill the CPT, and time spent.

In general Bayesian Network looks like useful tools for analysis of watershed management, even they have or no a monitoring system like the case studied.

To use Bayesian Network, as Decision Support system tools in Watershed Management will require a supporting monitoring system with indicators of activity and impact, otherwise will consume so much time, and instead to facilitate the process will obstruct it.

7 Conclusions and Recommendations

7.1 Watershed Management

Conclusions

- There are no documented studies about the relationships between physical and non-physical variables in watershed management.
- The most effective way of achieving sustainable watershed management is through achieving autonomy in watershed management.
- Broadly focussed programs or projects in watershed management, tend to focalise their efforts in the achievement of the physical goals contemplated in the list of disbursement or investment (translated as activity indicators), missing the objectives of an efficient watershed management; besides these broadly focussed programs or projects, disperse efforts in diminish of the efficiency and efficacy of the developed activities.
- Watershed Management in Peru is focused in the Sierra region, with a strong intervention of the Government through Programs and Projects as the **National program of watershed management and soil conservation** (PRONAMACHCS). The participatory approach is understood as the participation of the communities through a labour contribution to watershed management activities, more than a role of controlling or participating in the decision making process.
- PRONAMACHCS intervention in watershed management is focused on technical assistance and management capacity to control soil erosion and to improve the productive activities. Some of this interventions have created a strong dependency on part of the watersheds under PRONAMACHCS scope making them unsustainable, due to the high level of political uncertainty in Peru, where this type of program can disappear from one day to other.
- Despite that Ayas community is considered as one that achievement success in the **Peru – Sierra natural resources management and poverty alleviation project**, has not reached the project objectives, that is to say, has low autonomy, is under the poverty line, and it is not enough sustainable.
- Even though there is high uncertainty about the total area of land use in Ayas watershed, it has been shown through the Bayesian Network that income is more related with the availability of physical resources, and management activities (training, fencing, cultivation, etc.) are more related with sustainable land use.

Recommendations

- Promote the watershed analysis using tools like Bayesian Networks in order to document the relationships that can be established between physical and non-physical variables in watershed management.
- The World Bank should promote more the execution of small scale Projects in watershed management with special attention in the fulfilment of the objectives through periodical evaluation of the watershed management, with the implementation of monitoring systems based not only on activity indicators.

- PRONAMACHCS have to redefine it paternalist role with a more promoting role through changes in the policies of incentives for participation. Improve it actual monitoring system.
- PRONAMACHCS have to implement in Ayas watershed management a strategy for a suitable land use and a program to expand the areas used under the constraint of labour availability
- The community of Ayas have to put more attention to vicuna fibre production, taking advantages of the existent legal framework and market privileges.

7.2 Bayesian Network Usefulness

Conclusions

- Really, Bayesian Network provide a effective mathematical framework for facilitating the integrated analysis of physical and non-physical variables in a watershed, giving a better understanding of the watershed system, as the interaction between the variables involved.
- Participation of stakeholders involved in the watershed management in the Bayesian Network building process will facilitate the process reducing the time consumed by this activity, and improving the quality of the model developed.
- The implementation of decision support system tools like Bayesian Network in Peru sierra watershed management will not be possible until a monitoring system or system information is available. The analysis of watershed using Bayesian Networks will provide a framework to establish which are the indicators needed to implement an efficient and effective monitoring system.

Recommendations

- Bayesian Networks are easier to understand if it uses a minimum number of nodes. In the building process and conception of the Network try to limit the number of nodes.
- The implementation of Decision Support system tools in the Peru – Sierra watershed management will only be possible if the monitoring of activities is systematized, using not only activity indictors, also impact indicators.

7.3 Limitations to the study

It was not possible to evaluate PRONAMACHCS intervention effectiveness in terms of technical and management capacity, because of data availability and lack of indicators of those activities like assistance to training courses.

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ANNEXES

Annex I: Watershed Characteristics

Annex II: Bayesian Networks Nodes, and CPTS

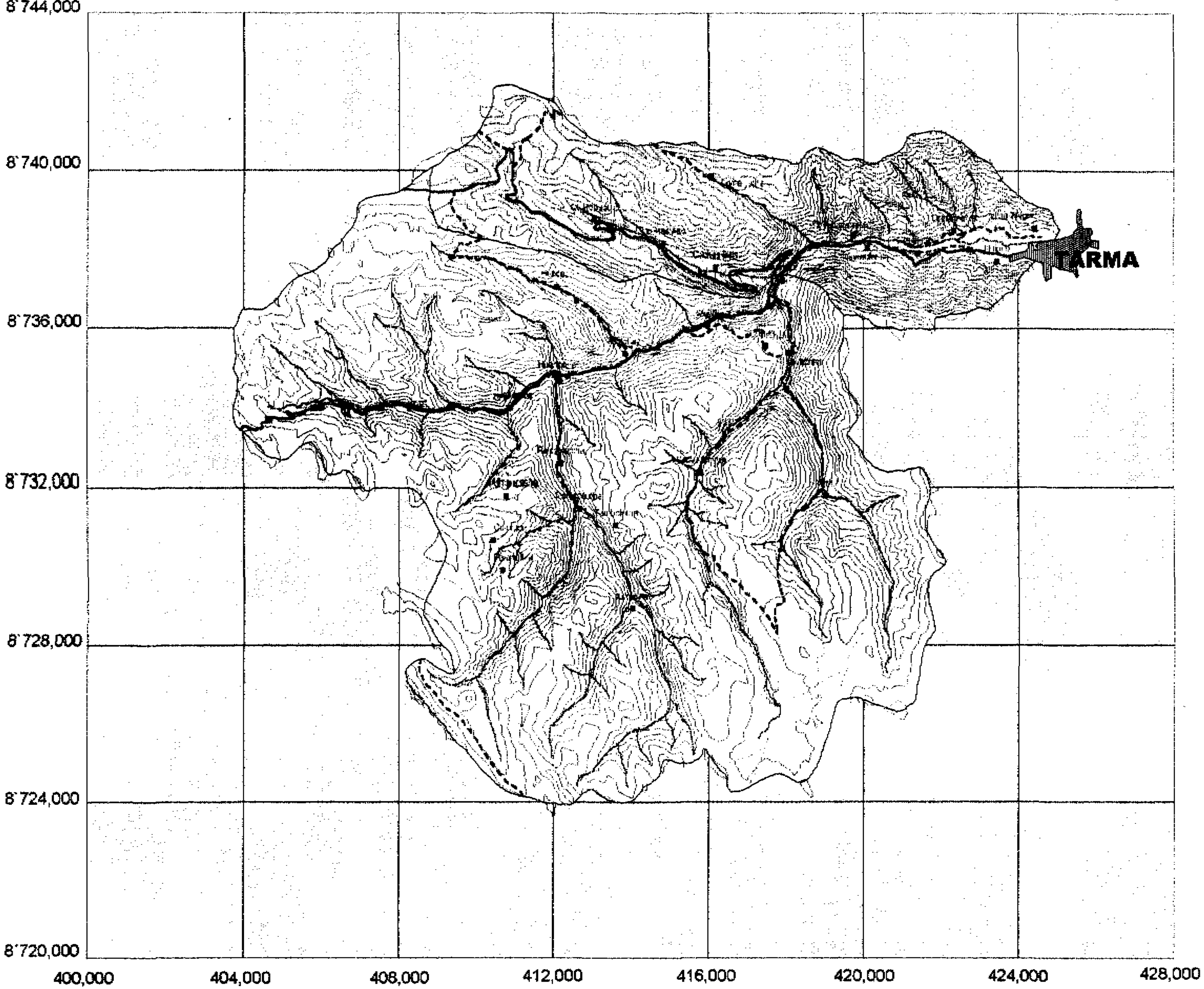
Annex III: Sensitivity Analysis

Annex IV: Bayesian Networks Graphs

Annex I: Watershed Characteristics

MINISTERIO DE AGRICULTURA
PRONAMACHCS TARMA - YAULI - JUNIN
SUB-PROYECTO MIMA TARMA

MAPA BASE DE LAS MICROCUENCAS MULLUCRO Y MUYLO



LEYENDA

Ciudad de Tarma
Comunidades y Anexos
Curvas de nivel
Vias de comunicacion
Carretera Asfaltada
Carretera Afirmada
Camino de Herradura
Red hidrografica
Limite Microcuenca
Mullucro
Muylo
Coordenadas UTM

ESCALA GRAFICA
1 0 1 2 Kilometers

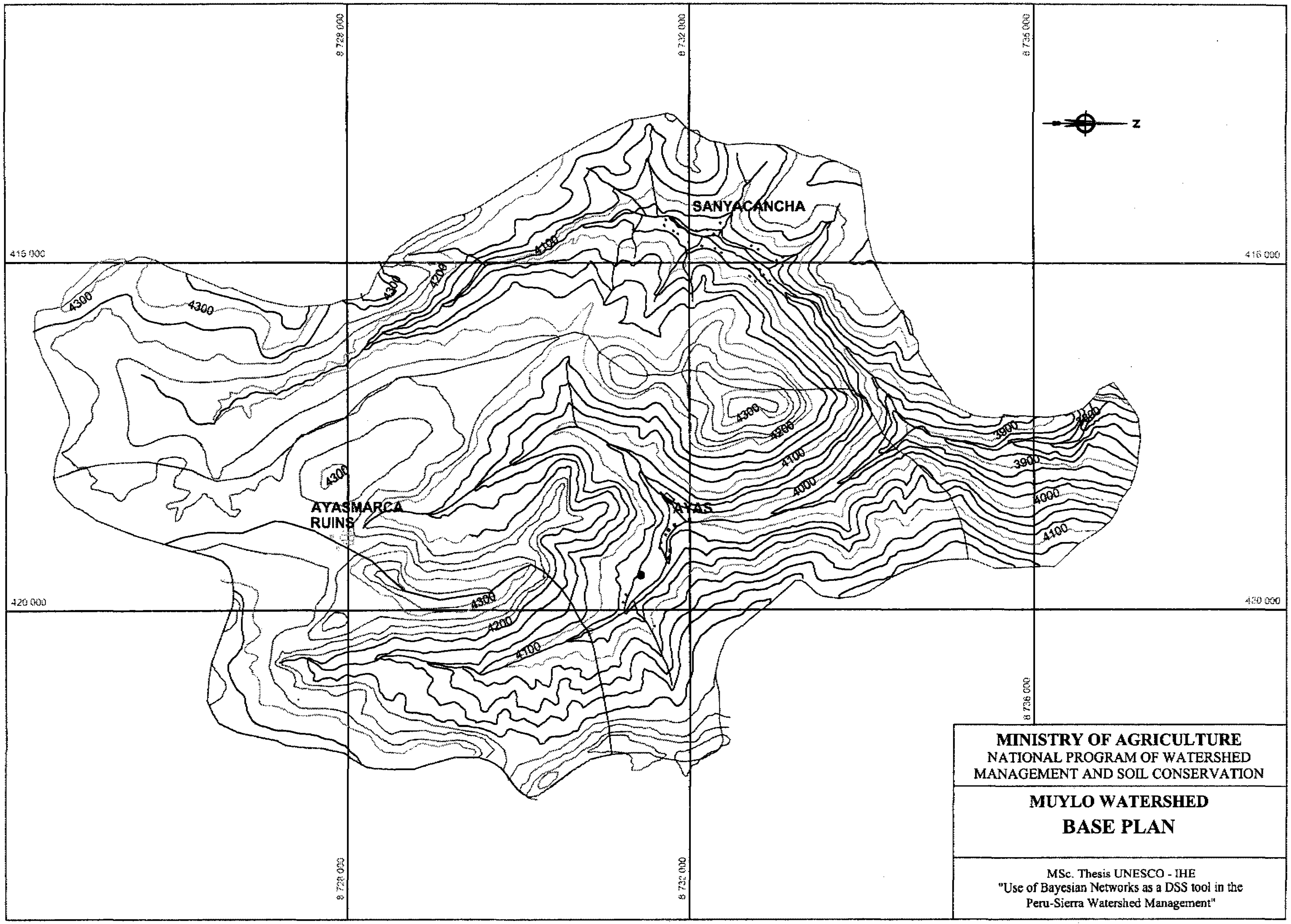
FUENTE :
MOSAICO DE HOJAS DE RESTITUCION FOTOGRAMETRICA A ESCALA 1:25,000

ELABORADO POR : ING. A. REDAÑEZ
ESPECIALISTA SIG

REVISADO POR : ING. A. SOSA
COORDINADOR MIMA

APROBADO POR : ING. J. GARCIA
JEFE AGENCIA ZONAL

FECHA : TARMA, OCTUBRE 2,002



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8 732 000
8 735 000
8 736 000
416 000
420 000
Z
SANYACANCHA
AYASMARCA
RUINS
AYAS
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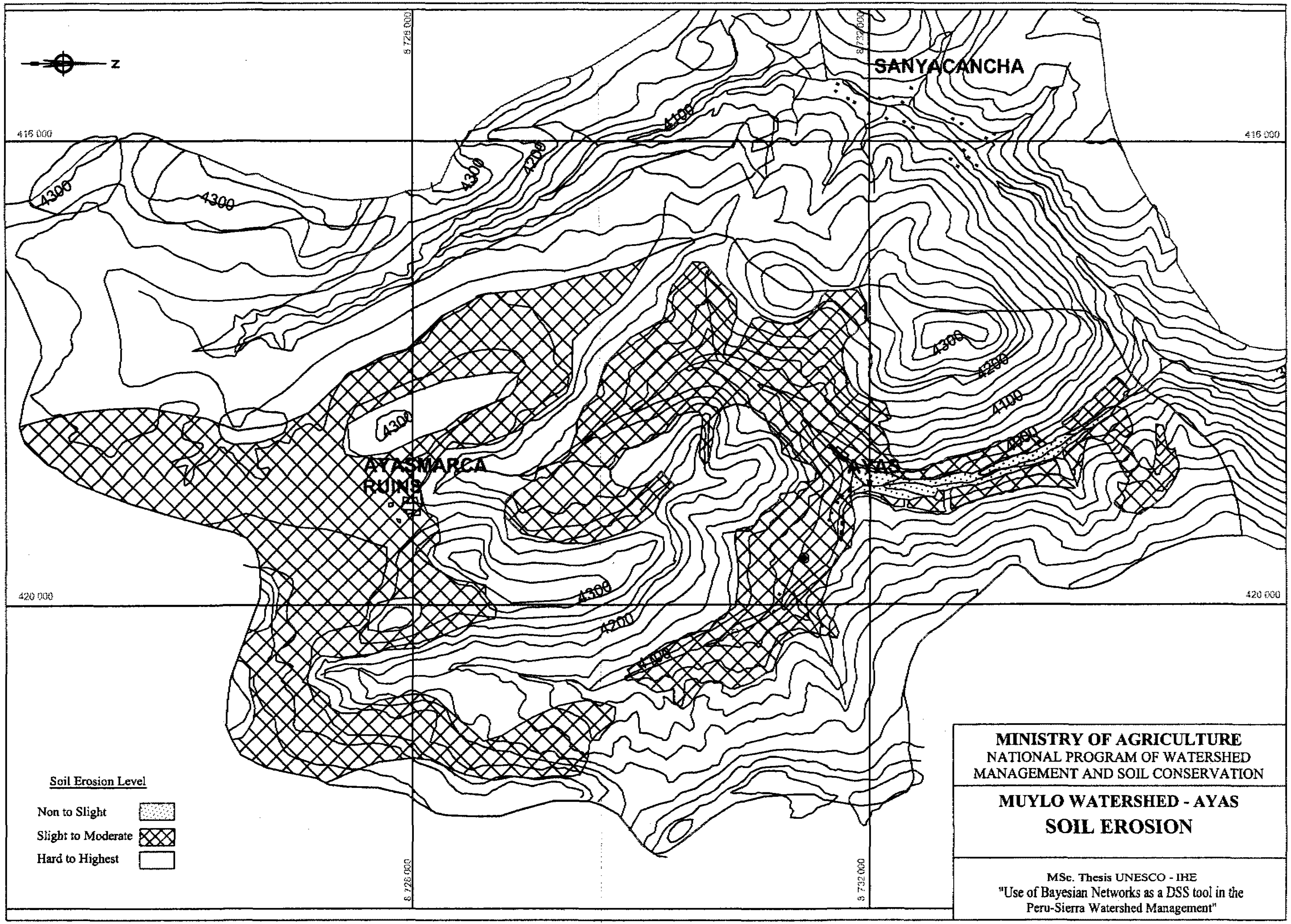
4100
4000
3900
MINISTRY OF AGRICULTURE
NATIONAL PROGRAM OF WATERSHED
MANAGEMENT AND SOIL CONSERVATION
MUYLO WATERSHED
BASE PLAN
MSc. Thesis UNESCO - IHE
"Use of Bayesian Networks as a DSS tool in the
Peru-Sierra Watershed Management"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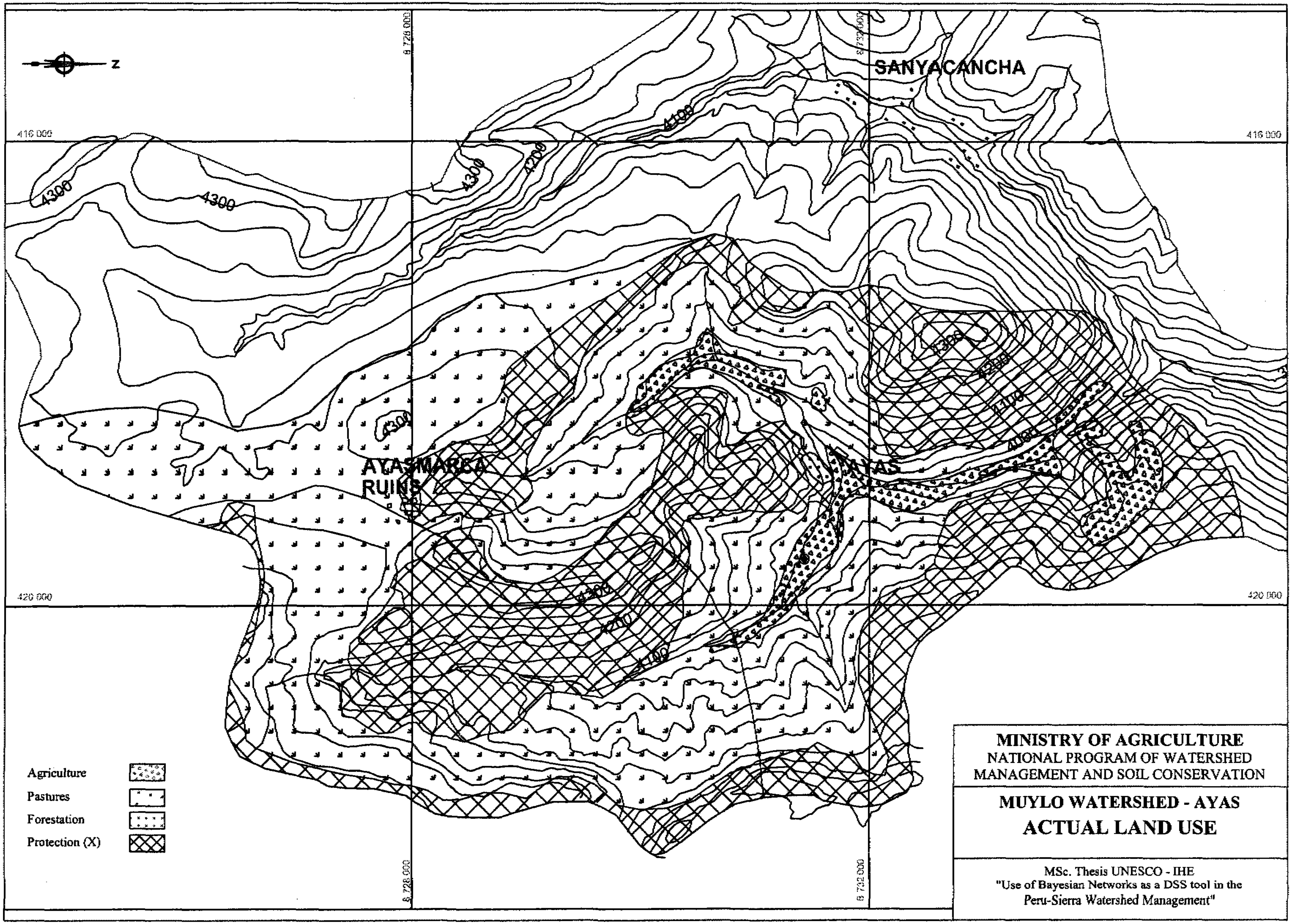
Soil Erosion Level
Non to Slight
Slight to Moderate
Hard to Highest
MINISTRY OF AGRICULTURE
NATIONAL PROGRAM OF WATERSHED
MANAGEMENT AND SOIL CONSERVATION
MUYLO WATERSHED - AYAS
SOIL EROSION
MSc. Thesis UNESCO - IHE
"Use of Bayesian Networks as a DSS tool in the
Peru-Sierra Watershed Management"



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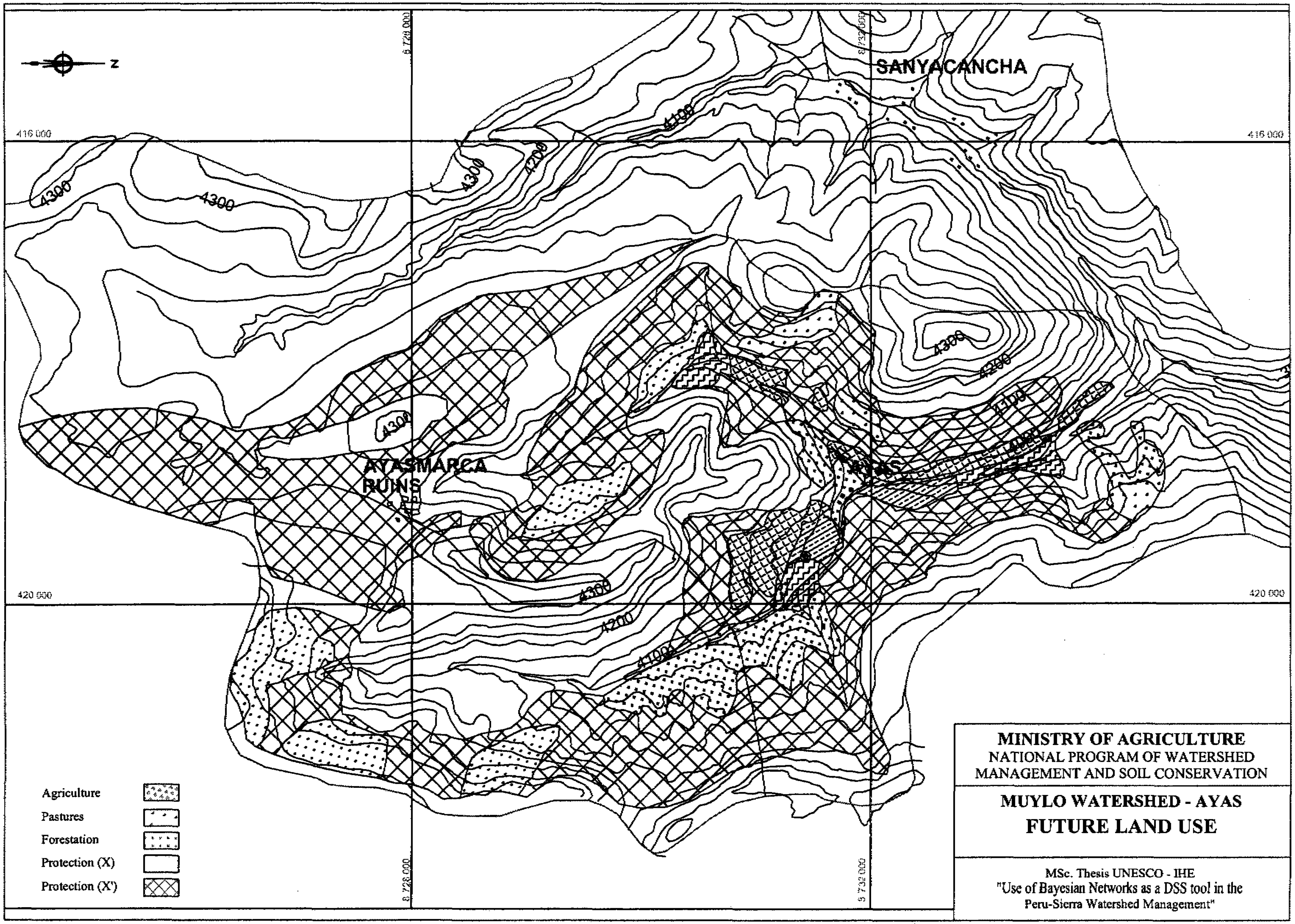
8 732 000
Agriculture
Pastures
Forestation
Protection (X)
MINISTRY OF AGRICULTURE
NATIONAL PROGRAM OF WATERSHED
MANAGEMENT AND SOIL CONSERVATION
MUYLO WATERSHED - AYAS
ACTUAL LAND USE
MSc. Thesis UNESCO - IHE
"Use of Bayesian Networks as a DSS tool in the
Peru-Sierra Watershed Management"



MINISTRY OF AGRICULTURE
NATIONAL PROGRAM OF WATERSHED MANAGEMENT AND SOIL CONSERVATION
MUYLO WATERSHED - AYAS
FUTURE LAND USE
MSc. Thesis UNESCO - IHE
"Use of Bayesian Networks as a DSS tool in the Peru-Sierra Watershed Management"
Agriculture
Pastures
Forestation
Protection (X)
Protection (X')
SANYACANCHA
AYASMARCA RUINS
AYAS
4300
4200
4100
416 000
420 000
8 728 000
8 732 000

Fecha: 2001 (Month?)

FORMATO PARA RECOJO DE DATOS FARMOD

I. DATOS GENERALES DE LA ORGANIZACIÓN CAMPESINA

1. NOMBRE DE LA ORGANIZACIÓN CAMPESINA: COMUNIDAD CAMPESINA DE AYAS

2. DEPARTAMENTO: JUNIN PROVINCIA: TARMA
DISTRITO: TARMA MICROCUENCA: MUYLO

3. VIAS DE ACCESO A LA ORGANIZACIÓN CAMPESINA [Indicar, la ruta de acceso, el tipo de vía (asfaltada o afirmada) y además a cuantos kilómetros de la capital de provincia se encuentra]:
LA VIA DE ACCESO PRINCIPAL ES LA CARRETERA ASFALTADA TARMA - OROYA, PARTIENDO DE TARMA HASTA HUASQUI (9. KM - ASFALTADA), LUEGO SE INGRESA DESDE HUASQUI HASTA AYAS (6 KM - CARRETERA AFIRMADA) LA CUAL VIENE A SER 15 KM. DESDE TARMA HASTA AYAS

4. ALTITUD DE LA ORGANIZACIÓN CAMPESINA (m.s.n.m.): MÁXIMA: 4250 MÍNIMA: 3650 } Jalca o Suni

5. TEMPERATURA EN LA ORGANIZACIÓN CAMPESINA (°C): MÁXIMA: 21.7°C MÍNIMA: -4.1°C

6. PRECIPITACIÓN MEDIA ANUAL: 541.30 mm.

7. ¿DESDE QUE AÑO TRABAJA LA ORGANIZACIÓN CON PRONAMACHCS? 1994

8. ¿DESDE QUE AÑO TRABAJA LA ORGANIZACIÓN CON EL PROYECTO ALIVIO / BANCO MUNDIAL? 1998

9. NÚMERO TOTAL DE FAMILIAS DE LA COMUNIDAD Y LA ORGANIZACIÓN CAMPESINA [no confundir familias con población]:
9.1 DE LA COMUNIDAD / ANEXO / CASERÍO / PARCIALIDAD: 24 FAMILIAS
9.2 TRABAJAN CON EL PROYECTO ALIVIO /BANCO MUNDIAL: 18 FAMILIAS

10. ACTIVIDADES ECONÓMICAS DE LAS FAMILIAS DE LA ORGANIZACIÓN CAMPESINA:

ACTIVIDAD PRINCIPAL: GANADERIA

ACTIVIDADES SECUNDARIAS: AGRICULTURA

11. RECURSO SUELO DE LA ORGANIZACIÓN CAMPESINA:

SUPERFICIE	HECTÁREAS
AGRÍCOLA CON RIEGO	36.00
AGRÍCOLA SIN RIEGO	474.00
PARA PASTIZALES	1369.00
PARA FORESTALES	510.00
PARA OTROS	
DE PROTECCIÓN O MISCELANEOS	800.18
TOTAL	3189.18

12. POBLACIÓN GANADERA DE LA ORGANIZACIÓN CAMPESINA:

ESPECIE GANADERA	N° DE CABEZAS	ESPECIE GANADERA	N° DE CABEZAS
VACUNOS	137	PORCINOS	08
OVINOS	1200	EQUINOS	12
CAPRINOS	—	CAMÉLIDOS SUDAMERICANOS	377

ALPACAS 12[illegible]
VICUÑAS 10[illegible]

13. OTROS RECURSOS NO AGRÍCOLAS:

14. CARACTERÍSTICAS PRINCIPALES DE LOS RECURSOS Y DE LA ACTIVIDAD AGROPECUARIA EN LA ORGANIZACIÓN CAMPESINA

CALIDAD DE SUELOS
- [X] POBRE
- [X] POCO FÉRTIL
- [ ] MEDIANAMENTE FERTIL
- [ ] MUY FERTIL

PENDIENTE
- [X] EMPINADO O ACCIDENTADO
- [X] LIGERAMENTE ACCIDENTADO
- [X] LIGERAMENTE INCLINADO
- [ ] CASI A NIVEL

PRINCIPALES FUENTES DE AGUA
- [X] MANANTIAL
- [ ] OJOS DE AGUA O PUQUIAL
- [ ] RÍO O QUEBRADA
- [ ] LAGUNA
- [X] CANAL DE RIEGO
- [X] RESERVORIO

PRÁCTICAS AGRÍCOLAS Y PECUARIAS
- [ ] USO INTENSIVO DE FERTILIZANTES QUÍMICOS Y PESTICIDAS
- [X] USO DE FERTILIZANTES ORGÁNICOS
- [X] PRACTICAN ROTACIÓN DE CULTIVOS
- [X] UTILIZAN MAQUINARIA AGRÍCOLA
- [X] UTILIZAN YUNTAS/ OTRAS HERRAMIENTAS ARTESANALES
- [X] CRIANZA EXTENSIVA DE GANADO
- [ ] CRIANZA INTENSIVA DE GANADO

TIPOS DE PRODUCCIÓN
- [ ] MONOCULTIVO
- [ ] CULTIVOS ASOCIADOS
- [X] VARIOS CULTIVOS

DESTINO DE LA PRODUCCIÓN
- [ ] AUTOCONSUMO
- [X] AUTOCONSUMO Y UNA PARTE VA AL MERCADO
- [ ] MAYOR PARTE VA AL MERCADO

15. SERVICIOS PARA LA PRODUCCIÓN EN LA MICROCUENCA (MOLINOS, ALMACENES, PLANTAS AGROINDUSTRIALES, ETC.):

TIPO	CANTIDAD
MOLINOS	—
ALMACENES (SILO)	01
TRILLADORAS	—
PLANTAS AGROINDUSTRIALES	01

Módulo: Transformación de Productos Lácteos

16. LUGARES DE VENTA Y DESTINO DE LOS PRODUCTOS AGROPECUARIOS DE LA ORGANIZACIÓN CAMPESINA:

- [ ] EN LA PARCELA
- [ ] EN FERIAS
- [ ] EN MERCADO DISTRITAL
- [X] EN MERCADO PROVINCIAL
- [ ] EN MERCADO REGIONAL
- [ ] EN MERCADO DE LIMA

17. OTRAS INSTITUCIONES PÚBLICAS Y PRIVADAS QUE TRABAJAN EN LA ORGANIZACIÓN CAMPESINA:

NOMBRE DE LA INSTITUCIÓN / PROYECTO / ONG	ACTIVIDAD QUE REALIZA LA INSTITUCIÓN / PROYECTO / ONG	AÑO DE INICIO Y TÉRMINO DE LA ACTIVIDAD	
		INICIO	TÉRMINO
CONACS	Asesoramiento Técnico en Camélidos	1995	
UNCP (Univ. Nac. del Centro del Perú)	Investigación y Mejoram. Genético	2001	
INIA - HUANCAYO	Investigación en pastos	2000	
PRONAA	Asistencia Social (COMEDOR)	2000	
MUNICIPALIDAD PROV. DE TARMA	Asistencia Social (Prog. Vaso de Leche	1990	
MINISTERIO DE EDUCACION	Educación (Escuela Primaria	1990	

18. SERVICIOS BÁSICOS EN LA ORGANIZACIÓN CAMPESINA

- [X] ENERGÍA ELÉCTRICA
- [ ] DESAGUE
- [X] AGUA POTABLE
- [ ] TELÉFONO COMUNITARIO

19. PUESTO DE SALUD MÁS CERCANO A DONDE ACUDEN LAS FAMILIAS DE LA ORGANIZACIÓN CAMPESINA:

LUGAR: CASERIO DURAZNIOC DISTANCIA DE LA ORGANIZACIÓN: 04 Km.

20. DISPONIBILIDAD DE CENTROS EDUCATIVOS O DE FORMACIÓN PROFESIONAL CERCANOS A LA ORGANIZACIÓN:

	CANTIDAD	DISTANCIA DE LA ORGANIZACIÓN (Km.)
WAWAWASI	—	—
JARDÍN DE INFANCIA	—	—
ESCUELAS	01	MISMO LUGAR
COLEGIOS	05	15 KM.
INSTITUTO SUPERIOR	02	15 KM.

21. ACCIONES DE CONSERVACIÓN REALIZADAS CON EL PROYECTO EN LA ORGANIZACIÓN CAMPESINA (DESDE QUE EMPEZÓ EL PROYECTO ALIVIO HASTA DICIEMBRE 2001):

21.1 DESARROLLO FORESTAL

OBRAS Y ACTIVIDADES		1997	1998	1999	2000	2001
INSTALACIÓN O MEJORAMIENTO DE VIVEROS	UNIDADES					
PRODUCCIÓN DE PLANTONES	MILES DE PLANTONES		31,721	23,339	18212	3740
ESTABLECIMIENTO DE PLANTACIONES	HECTÁREAS		13.42	9.09	16.5	3.5
	Nº FAMILIAS BENEF		24	24	24	24
MANEJO FORESTAL	HECTÁREAS		11.50	8.3	6.5	—
INVERSIONES TOTALES	HERRAMIENTAS (MILES DE SOLES)		6108.15	3728.05	2082.40	737.80
	INSUMOS: Semillas, abonos, fertilizantes, pesticidas, otros. (MILES DE SOLES)		2671.20	2850.10	913.37	450.00
	APORTE COMUNAL Mano de Obra (MILES DE SOLES		27,182.00	19,452.00	20,832.00	3900.00
	APORTE COMUNAL Materiales de la Zona (MILES DE SOLES)		650.00	650.00	650.00	650.00
	ASISTENCIA TÉCNICA PRONAMACHCS		2859.04	2859.04	2859.04	2859.04

21.2 CONSERVACIÓN DE SUELOS

OBRAS		1997	1998	1999	2000	2001
REHABILITACIÓN DE ANDENES	HECTÁREAS					
	N° DE FAMILIAS BENEFICIADAS					
TERRAZAS DE ABSORCIÓN	HECTÁREAS			0.242		0.10
	N° DE FAMILIAS BENEFICIADAS			24		24
TERRAZAS DE FORMACIÓN LENTA	HECTÁREAS		0.744	1.399		0.185
	N° DE FAMILIAS BENEFICIADAS		24	24		24
ZANJAS DE INFILTRACIÓN	HECTÁREAS		78.354	4.365		
	N° DE FAMILIAS BENEFICIADAS		24	24		
CAMINOS RURALES	KILÓMETROS					
	N° DE FAMILIAS BENEFICIADAS					
INVERSIONES TOTALES	HERRAMIENTAS (MILES DE SOLES)		21,474.00	2,001.87	202.70	508.00
	M. O. COMUNAL (MILES DE SOLES)		99,024.00	21,900.00	—	4248.00
	ASISTENCIA TÉCNICA PRONAMACHCS		2,859.04	2,859.04		2859.04

21.3 INFRAESTRUCTURA RURAL

OBRAS		1997	1998	1999	2000	2001
CANALES DE RIEGO	KILÓMETROS					
	AREA IRRIGADA (ha.)					
	N° DE FAMILIAS BENEFICIADAS					
RESERVORIOS	UNIDADES			01		
	METROS CÚBICOS			1000		
	AREA IRRIGADA (ha.)					
	N° DE FAMILIAS BENEFICIADAS			24		
SAUM	UNIDADES					
	METROS CÚBICOS					
	N° DE FAMILIAS BENEFICIADAS					
DEFENSAS RIBEREÑAS	KILÓMETROS					
	N° DE FAMILIAS BENEFICIADAS					
SISTEMAS DE RIEGO PRESURIZADO	N° DE MÓDULOS				01	
	AREA IRRIGADA (ha.)				24	
	N° DE FAMILIAS BENEFICIADAS					
INVERSIONES TOTALES	MATERIALES DE CONSTRUCCIÓN Y AGREGADOS (MILES DE SOLES)			18,198.60	38,787.00	
	M.O. CALIFICADA (MILES DE SOLES)			6,066.20	12,929.00	
	APORTE COMUNAL Mano de Obra (MILES DE SOLES			3,033.10	6,464.50	
	APORTE COMUNAL Material de la Zona (MILES DE SOLES)			—	—	
	ASISTENCIA TÉCNICA PRONAMACHCS			3,033.10	6,464.50	

21.4 APOYO A LA PRODUCCIÓN

OBRAS		1997	1998	1999	2000	2001
ALMACENES RURALES	UNIDADES				1	
	N° DE FAMILIAS BENEFICIADAS				24	
INSTALACIÓN DE CULTIVOS PARA SEMILLEROS	HECTÁREAS					
	N° DE FAMILIAS BENEFICIADAS					
INSTALACIÓN DE CULTIVOS PARA CONSUMO	HECTÁREAS		5.0	6.75	5.56	2.00
	N° DE FAMILIAS BENEFICIADAS		24	24	24	24
PRACTICAS AGRONOMICAS CULTURALES EN LADERAS	HECTÁREAS					
	N° DE FAMILIAS BENEFICIADAS					
APOYO AL MANEJO DE PASTOS NATIVOS Y BOFEDALES	HECTÁREAS				6.67	
	N° DE FAMILIAS BENEFICIADAS				24	
APOYO AL MANEJO DE PASTOS CULTIVADOS	HECTÁREAS				3.34	
	N° DE FAMILIAS BENEFICIADAS				24	

INVERSIONES TOTALES	M.O. CALIFICADA (MILES DE SOLES)					
	APORTE COMUNAL Mano de Obra (MILES DE SOLES		6,060.00	8,184.00	11,556.00	2,424.00
	APORTE COMUNAL Material de la Zona (MILES DE SOLES)		2,000.00	2,700.00	2 224.00	800.00
	HERRAMIENTAS (MILES DE SOLES)					
	INSUMOS Semillas, abonos, fertilizantes, pesticidas, otros. (MILES DE SOLES)		5929.80	6287.08	58,668.37	1240.00
	ASISTENCIA TÉCNICA PRONAMACHCS		2859.04	2859.04	2859.04	2859.04

21.5 CAPACITACIÓN

OBRAS		1997	1998	1999	2000	2001
CURSOS PARA PROMOTORES CAMPESINOS	N° DE CURSOS		01		01	
	N° DE BENEF.		40		47	
CURSOS PARA PRODUCTORES BENEFICIARIOS	N° DE CURSOS		01	04	04	10
	N° DE BENEF.		63	283	98	260
INICIATIVAS EMPRESARIALES	CANTIDAD		01			
	N° DE FAMILIAS BENEFICIADAS		24			

INVERSIONES TOTALES	COSTO TOTAL (MILES DE SOLES)		5100	2900	8200	12,200
	ASISTENCIA TÉCNICA PRONAMACHCS					

22. PADRÓN DEL COMITÉ CONSERVACIONISTA DE LA ORGANIZACIÓN CAMPESINA

NOMBRES Y APELLIDOS DEL JEFE DE FAMILIA	EDAD	Nº HECTÁREAS DE TERRENO PROPIO QUE EXPLOTA EN LA COMUNIDAD, (ANEXO, CASERÍO, PARCIALIDAD)	Nº TOTAL DE DEPENDIENTES (CÓNYUGUE E HIJOS)
1. JESUS CARLOS BERROSPI RIVERA	39	0.25	7
2. JUAQUIN ROJAS OSORIO	63	0.25	1
3. SIMEON VELIZ ARROYO	48	0.25	12
4. EUSEBIO JORGE ROJAS VELIZ	40	0.25	7
5. CLODOALDO MONTALVO FLORES	42	0.25	4
6. FORTUNATO COCHACHI BRICEÑO	54	0.25	3
7. VIDAL VENTURA CACERES	60	0.25	3
8. MIGUEL AMARO PIZARRO	31	0.25	5
9. JUANA PIZARRO ROJAS	57	0.25	4
10. HILARIA ROJAS PUCHOC	56	0.25	2
11. EVARISTA PIZARRO ROJAS	45	0.25	6
12. MARIA ROSA ROJAS VELIZ	39	0.25	4
13 JUANA POMA RIVERA	51	0.25	4
14. ISIDORO ROJAS VELIZ	34	0.25	4
15. PEDRO ROJAS VELIZ	31	0.25	3
16. EPIFANIA JURADO RODRIGUEZ	54	0.25	3
17. OSCAR LAUREANO CASO ROJAS	36	0.25	6
18. DELIA MACHUCA OSORIO	28	0.25	2
19.			
20. TOTAL		4.50	80 +18
21.			
22. But there are 24 families ⇨	6x.25 =	1.50	≈6x4 = 24
23.		6.00	
24.			
25. 3189 - 6 = 3183			
26. ⇨ 132.62 ha			
27.			
28. 6 families more	→	6x4 =	24
29.			
30.			
31.			
32.			
33.			
34.			
35.			
36.			
37.			

Subject: **Respuesta a consultas**
Date: Tue, 07 Jan 2003 17:58:09 +0000
From: "Alcides SOSA VALENZUELA" <sosal57@hotmail.com>
To: aranc@ihe.nl

Ing. Arancibia, previo cordial saludo y con los mejores deseos de èxitos para el presente año, adjunto le remito la respuesta a las preguntas que planteo en sus mensajes, lamentablemente mi ausencia por participar en un evento fuera del país ademàs de que recien se normalizaron las labores en el Perú no permitieron responderle antes, me parece ineteresane el trabajo que viene desarrollano, va a ser un buen aporte para el PRONAMACHCS.
Sin otro particular me despido,
Alcides Sosa

---

para ADA ARANCIBIA.doc	**Name:** para ADA ARANCIBIA.doc **Type:** WINWORD File (application/msword) **Encoding:** base64 **Download Status:** Not downloaded with message

Tarma, 13 de Mayo del 2003

Estimada Ing. Arancibia:

Doy respuesta las interrogantes de su misiva, las mismas que son las siguientes:

1. Sobre la cantidad de familias de la comunidad, son 24 familias que viven en la comunidad de Ayas, de éstas 18 familias son comuneros activos, hay 04 familias que son jubiladas, es decir que pasado un límite de edad se jubilan, ya no participan activamente en las faenas comunales pero si mantienen algunos derechos; igualmente hay 02 familias que han pedido licencia temporal y están radicando en la ciudad. Tres familias se retiraron de la comunidad por problemas familiares.
2. La producción dada esta en kgs.; los cultivos de papa, arverja, haba, son regados con riego por inundación, tienen un canal de riego con esa finalidad, los cultivos de avena y cebada son sembrados en terrenos de secano, ósea sólo con lluvias; los que tienen riego por aspersión son los pastos cultivados.
3. El agua proviene del puquial quinualpuquio, la diferencia de los datos del distrito de riego, es que están inscritos en este organismo sólo con 9.08 has. Y no han regularizado la diferencia, probablemente para que realicen menores pagos; no explican porque la diferencia.
4. Los beneficios del incremento de producción de leche, sólo es compartido con las 18 familias activas.
5. En relación a la fibra de vicuña la producción va de 100 a 200 grs. Por animal, precio promedio de 300 dólares kilo; han realizado a la fecha 3 ventas en igual número de años, de los cuales les han cancelado de dos ventas y queda pendiente el pago de la última venta, realizan el chakú cada año y tienen suficientes recursos para la crianza de más vicuñas que en el momento son de 80 a 100 vicuñas, no hay numero fijo porque a veces las vicuñas se van a otros lugares, en los primeros años han esquilado aproximadamente de 30 a 40 animales, porque dependía de la captura que hacían en los chakus; en cuanto a alpacas el número es de 200 alpacas, la lana de la vicuña huacaya está 3.80 Nuevos Sóles la libra y el de Suri 5.00 Nuevos sóles la libra, no tienen plan de comercialización de la venta de esta fibra, lo comercializan limitadamente.

Esperando haber aclarado sus dudas, me despido con cordiales saludos.

Atentamente,

ALCIDES SOSA

REQUEST FOR EXPERT OPINION

Dear Dr. Charles Batchelor

I am an MsC student from IHE, in the programme of Water Resources Management. Currently I am working in my thesis research with Patrick Moriarty, the topic is "Use of Bayesian Networks as a Decision Support System Tool in the Peru-Sierra watershed management".

I am working in a small watershed. In this watershed the Peruvian government has been working in programmes of soil conservation with the local communities since 1994. Since 1998 the government is working with the Peru –Sierra Natural Resources Management and Poverty Alleviation Project in more than 125 watersheds including this one. The small watersheds are lack of data that is why the using of Bayesian Networks is a good alternative, because the lack of data can be fed by expert's opinion.

Due to your broad experience in watershed management and water harvesting, I feel confident to ask your opinion for develop my thesis.

The focus is on small watershed 800 ha which feeds a spring used for irrigation. One of the main activities of the project is rehabilitation of the catchment using furrows. Located in the upper part of the watershed, the furrows will diminish runoff and increase infiltration.

We are interested in your beliefs regarding the liked impacts of this treatment method under different conditions of rainfall and area treated. We assume that the furrows are correctly designed and maintained.

I would appreciate if you could use your experience to fill in the conditional probability table below by assigning a probability to each combination of treated area and rainfall.
For instance the belief of increase in Q_{spring} for a catchment area treated from 0 to 25% with rainfall from 0 to 600 mm, could have a probability of 90% to increase in 0 to 10 %, probability of 10% to increase in 10 to 30 %, and cero in the other cases.

Conditional Probability Table. Annual Precipitation

Catchment area treated %	Rainfall (mm)	Increase Qspring in dry season %			
		0 - 10	10 - 30	30 - 60	60 - 100
0-25	0-600	90	10	0	0 Σ=100%
0-25	600-750				
0-25	750-900				
25-50	0-600				
25-50	600-750				
25-50	750-900				
50-75	0-600				
50-75	600-750				
50-75	750-900				
75-100	0-600				
75-100	600-750				
75-100	750-900				

General Available Information

As a reference

Record in a gauge station in the low area (3 500 meters above sea level)

Unit	MONTHS												ANUAL
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	
mm	36.8	27.8	39.7	74.5	84.9	67.6	60.4	37.2	17.7	3.6	10.6	10.3	471.1

Furrow infiltration area

Temperature: Max 6°C Min 3°C

Annual Precipitation: 600 mm to 800 mm

Level: 4000 to 4500 meters above sea level.

Soil: granite and sandstone. Drainage from good to bad.

Slopes from 4% to 20% and 16% to 60%

Spring Area

Temperature: Max 12°C Min 6°C

Annual Precipitation: 600 mm to 800 mm

Level: 3500 to 4000 meters above sea level.

Soil: Creek bed, alluvial. (karst formation. Limestone.)

Furrow infiltration area

Spring

Thank you very much for your attention.

Regards,

Ada Arancibia

ANSWER

Catchment area treated %	Rainfall (mm)	Increase Qspring in dry season			
		0-10	10 - 30	30 - 60	60 - 100
0-25	0-600	90	10	0	0
0-25	600-750	85	15	0	0
0-25	750-900	80	15	5	0
25-50	0-600	70	15	0	0
25-50	600-750	65	30	5	0
25-50	750-900	60	30	10	5
50-75	0-600	50	25	5	0
50-75	600-750	45	45	10	5
50-75	750-900	40	40	15	10
75-100	0-600	30	35	15	5
75-100	600-750	25	50	20	10
75-100	750-900	20	45	25	15

Some thoughts:

I have erred towards caution in filling in the table. Given the unpredictable nature of springs in limestone, I would not be too surprised in the treatments had a huge (or even no difference). My limestone experience of springs in limestone areas is from Palestine. In this area the presence of springs is influenced by the presence of calcrete layers and the sources of water (in terms of recharge) can be very localised and sometimes some considerable distance from the spring. Or put another way, if the task had been to fill in the CPT a different geology and for low flows in a river, I would have felt more confident.

Annex II: Node Cards

Title: Available Area1 (ha)
Name: Furrows_Area1:

114
1

Units: hectares
Definition: Area designed to furrow infiltration, located upstream the spring, that can infiltrate water and release in the spring.

Total available area 114 hectares

Title: Available Area2 (ha)
Name: Furrow_Area2:

PRONAMACHCS	Future	Actual
Intervention	0.1	0.9
No	0.1	0.9

Units: hectares
Definition: It is the area designed for furrow infiltration, that is outside of the influence area that infiltrate water to the spring.

Title: Treated_Area1
Name: Treated_Area:

PRONAMACHCS	Actual	Future
Intervention	0.9	0.1
No	0.9	0.1

Units: hectares
Definition: Area designed to furrow infiltration, that effective are in use by furrow infiltration

Current 83 hectares
Maximum or future 114 hectares

Title: Total Treated Area
Name: Total_FI_Area:

Furrow_ Area2	*Treated_ Area*	Total_FI_ Area
Future	Actual	160
Future	Future	160
Actual	Actual	83
Actual	Future	83

Units: hectares
Definition: Area with furrow infiltration, with or without seed grass. Ther are two areas, one that apport water to the spring, and other outside of the influence area of the spring

---

Title: % Treated Area 1
Name: Treated_Area1:

Furrows_ Area1	*Treated_Area*	Treated_ Area1
114	Actual	50 to 75
114	Future	75 to 100

Units: percentage
Definition: percentage of area with furrow infiltration works, from all the area in the influence area of the springe.
Actual land with furrow infiltration = 83 hectares => 83/114 ~ 73%
Future land with furrow infiltration = 114 hectares =>114/114 = 100%

Title: Rainfall (mm/year)
Name: Rainfall

0 to 600	600 to 750	750 to 900
0.3333	0.3333	0.3334

Units: mm/year
Definition: Rainfall, in the ranges defined according *Water Resources Inventory of Muylo - Mullucro Watershed*
There is not more information about that then the 3 states have the same probability of ocurrence

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Title: Available Water (m^3/year)
Name: Available_Water:

Treated_ Area1	*Rainfall*	50000	300000	1000000
0 to 25	0 to 600	1	0	0
0 to 25	600 to 750	0	1	0
0 to 25	750 to 900	0	0	1
25 to 50	0 to 600	1	0	0
25 to 50	600 to 750	0	0.95	0.05
25 to 50	750 to 900	0	0	1
50 to 75	0 to 600	1	0	0
50 to 75	600 to 750	0	0.9	0.1
50 to 75	750 to 900	0	0	1
75 to 100	0 to 600	1	0	0
75 to 100	600 to 750	0	0.75	0.25
75 to 100	750 to 900	0	0	1

Units: m^3 per year
Definition: Quantity of water is expected to release in the spring downstream, because of rainfall infiltration in the upper part, that be favored by the furrow infiltration

This CPT was filling after consultation to Dr. Batchellor
There is not information about type soil ranges of infiltration, or metheorological data, not records in the spring.

Title: Grass area to Irrigate (ha)
Name: Irrig_G_AreaT:

Current	*Future*
0.954545	0.0454546

Units: hectares
Definition: Area with grass, irrigated with sprinkler system, to sustain the cows.
Current area = 20 hectares
Future area = 30 hectares
The future area is a project, nothing concrete.

Title: Irrigation Efficiency
Name: Efficiency:

PRONAMACHCS	0.6	0.7
Intervention	0.1	0.9
No	0.6	0.4

Units: percentage
Definition: The actual irrigation system use sprinklers, and it is assumed have a effciiency of 70%, this system was implemented by PRONAMACHCS.
It is supposs that if there are not intervention by PRONAMACHCS there will not be sprinklers

Title: Irrigated grass area
Name: Irrig_G_Area:

Available_Water	*Irrig_G_AreaT*	*Efficiency*	Irrig_G_Area
50000	Current	0.6	6 to 14
50000	Current	0.7	6 to 14
50000	Future	0.6	6 to 14
50000	Future	0.7	6 to 14
300000	Current	0.6	14 to 22
300000	Current	0.7	14 to 22
300000	Future	0.6	14 to 22
300000	Future	0.7	14 to 22
1000000	Current	0.6	22 to 30
1000000	Current	0.7	22 to 30
1000000	Future	0.6	22 to 30
1000000	Future	0.7	22 to 30

Units: hectares
Definition: Area downstream of the spring, used to grow grass to feed cows. It is irrigated by a sprinkler system

The efficiency can change, for the purposes of this study range from 0.60 to 0.70, there is not report about this in the field.

The CPT was filled with the following relationship:
Irrig_G_Area =

If (Available_Water/10/(500/Efficiency) < = 20
=> Irrig_G_Area=(Available_Water/10/(500/Efficiency))
If (Available_Water/10/(500/Efficiency) < = 30
=> Irrig_G_Area=(Available_Water/10/(500/Efficiency))
Else Irrig_G_Area = Irrig_G_AreaT

Title: Total Milk Production ($/year)
Name: M_Income:

Irrig_G_Area	0 to 14500	14500 to 29000	29000 to 43500
10 to 16	1	0	0
16 to 22	0.71	0.29	0
22 to 30	0	0.34	0.66

Units: $ per year
Definition: Income due to production of milk, considering the price in market of:
The minimum are to produce milk is 14.60 hectares.
The CPT was filled used the following equation:

If (Irrig_G_Area <= 14.69)Then M_Income = 0
Else M_Income = (20*(1.60*Irrig_G_Area-23.47)*365)*0.24

Title: Area under grass (ha)
Name: Grass_Furrows:

PRONAMACHCS	0	3	10	20
Intervention	0.06	0.92	0.018	0.002
No	0.3	0.68	0.02	0

Units: hectares
Definition: Areas of furrow infiltration, that have been seed with native grass, to feed south american camelids. Current there are only 3 hectares with grass. If there is not maintenance it could disapear or can extend at rate of 10 hectares per year.

Title: Grass Cultivation
Name: Seeding:

Total_Cap	Adequate	Inadequate
High	0.9	0.1
Low	0.2	0.8

Units: adimensional
Definition: The areas with furrow infiltrations that are apropriate to seed native grass. The process of seeding is in charge of the campesinos, if they do it properly, then the area will have good supportability
It dependes of the Total Capacity.

Title: Fencing Treated Area (FI)
Name: Fencing:

Total_Cap	Adequate	Inadequate
High	0.9	0.1
Low	0.2	0.8

Units: adimensional
Definition: The areas of furrow infiltration with grass are fenced to protect the grass from the camels, and allow it to grow
The effectiveness of the fence, will depend of the Total capacity.

Title: Capacity Food Supply 1
Name: Grass_Supply:

Seeding	*Fencing*	1.5	3
Adequate	Adequate	0.05	0.95
Adequate	Inadequate	0.4	0.6
Inadequate	Adequate	0.6	0.4
Inadequate	Inadequate	0.95	0.05

Units: camelids per hectar
Definition: How many camels can be fed per hecatr, it means supportability. It depends of land type and land management.
In this case, the land use area is for furrow infiltration with seed grass, then it will have a high supportability if the seeding and fencing are adequate. See table 3.18

Title: South Camelids 3
Name: S_Camelids3:

Grass_ Supply	*Total_Fl_ Area*	*Grass_ Furrows*	S_Camelids3
1.5	83	0	0 to 20
1.5	83	3	0 to 20
1.5	83	10	20 to 40
1.5	83	20	20 to 40
1.5	160	0	20 to 40
1.5	160	3	20 to 40
1.5	160	10	20 to 40
1.5	160	20	40 to 60
3	83	0	0 to 20
3	83	3	0 to 20
3	83	10	20 to 40
3	83	20	20 to 40
3	160	0	20 to 40
3	160	3	20 to 40
3	160	10	40 to 60
3	160	20	40 to 60

Units: units of south-american camelids (alpacas or vicunas)
Definition: The number of camels that can be fed in the land designed for grass cultivation in the furrow infiltration area. This area can have high supportability, depending of the land management.

Title: Area with other similar structures
Name: Other_Similar:

PRONAMACHCS	14
Intervention	0.9
No	0.6

Units: hectares
Definition: Areas similar to the one used by furrow infiltration, in this case used to built terracies, andenes, etc
Because there is not enough information to defyne the areas, and their supportability, it assumed that Current area is 14 hectares.

Title: Capacity Food Supply 2
Name: Grass_Supply1:

Total_Cap	0.2	1.5	3
High	0.05	0.5	0.45
Low	0.6	0.3	0.1

Units: camelids per hectar
Definition: How many camelids can be fed per hectar, it means supportability. It depends of land type and land management. Total_Cap represents Land Management See Table 3.18

Title: South Camelids 2
Name: S_Camelids2:

Other_ Similar	*Grass_ Supply1*	S_Camelids2
14	0.2	0 to 15
14	1.5	15 to 30
14	3	30 to 45

Units: unit of camels
Definition: Quantity of camels can be fed in the area with other similar structures

Title: Protection Area (X')
Name: AreaX1:

1350
1

Units: Hectares
Definition: This area, has poor vegetation, and after some works of seeding native species will improve its supportability.
The area has a fixed value of 1354 hectares

Title: Capacity Food Supply 3
Name: Grass_Supply2:

Total_Cap	0.05	0.2
High	0.1	0.9
Low	0.9	0.1

Units: Camels per hectar
Definition: How many camelids can be fed per hectar.
In this case the land use of Protection Area (X') have limitations, and will have low supportability see table 3.19

Title: South Camelids 1
Name: S_Camelids1:

Grass_Supply2	AreaX'	S-Camelids
0.05	1350	0 to 140
0.20	1350	140 to 280

Units Units of camels
Definition The Area X', according the land use and land management can have suppotabilities for camels from 0.05 to 0.20 camels/hectar
Then this CPT was filled according the following relationship:
S_Camelids1 = Grass_Supply2 * AreaX1

Title: Camelids in Area(X)
Name: Camelids _AreaX:

68
1

Units Number of camelids fed by resources from Area (X)
Definition This area have poor vegetation, eroded, difficult access give a supportability of 0.05 camels/hectar
=> Camelids in Area(X) = 1343 x 0.05 = 67.15
See Table 3.18

Title: Total South Camelids
Name: Total_S_C:

S_Camelids1	S_Camelids2	S_Camelids3	Camelids AreaX	0 to 150	150 to 300	300 to 455
0 to 140	0 to 15	0 to 20	68	0.47	0.53	0
0 to 140	0 to 15	20 to 40	68	0.28	0.72	0
0 to 140	0 to 15	40 to 60	68	0.15	0.85	0
0 to 140	15 to 30	0 to 20	68	0.45	0.55	0
0 to 140	15 to 30	20 to 40	68	0.23	0.77	0
0 to 140	15 to 30	40 to 60	68	0.06	0.94	0
0 to 140	30 to 45	0 to 20	68	0.3	0.7	0
0 to 140	30 to 45	20 to 40	68	0.07	0.93	0
0 to 140	30 to 45	40 to 60	68	0	1	0
140 to 280	0 to 15	0 to 20	68	0	0.48	0.52
140 to 280	0 to 15	20 to 40	68	0	0.34	0.66
140 to 280	0 to 15	40 to 60	68	0	0.34	0.66
140 to 280	15 to 30	0 to 20	68	0	0.39	0.61
140 to 280	15 to 30	20 to 40	68	0	0.27	0.73
140 to 280	15 to 30	40 to 60	68	0	0.1	0.9
140 to 280	30 to 45	0 to 20	68	0	0.35	0.65
140 to 280	30 to 45	20 to 40	68	0	0.12	0.88
140 to 280	30 to 45	40 to 60	68	0	0.04	0.96

Units Units of camels
Definition The total amount of camels that the watershed can support.

The CPT is filled with the following equation:

Total_S_C =
S_Camelids1 +
S_Camelids2 +
S_Camelids3 +
Camelids_AreaX

Title: Vicunas
Name: Vicunas_F:

Total_S_C	0 to 40	40 to 80	80 to 100	100
0 to 150	0.19	0.26	0.15	0.4
150 to 300	0	0	0	1
300 to 455	0	0	0	1

Units Units of vicunas
Definition The community has 100 vicunas, a wild protected specy. Then fed this animals instead vicunas is a priority
The CPT was filled according this relation ship
If Total_S_C < 100 =>Vicunas_F = Total_S_C
Else Vicunas_F = Total_S_C

Title: Alpacas
Name: Alpacas_F:

Vicunas_F	Total_S_C	0 to 120	120 to 240	240 to 360
0 to 40	0 to 150	1	0	0
0 to 40	150 to 300	1	0	0
0 to 40	300 to 455	1	0	0
40 to 80	0 to 150	1	0	0
40 to 80	150 to 300	1	0	0
40 to 80	300 to 455	1	0	0
80 to 100	0 to 150	1	0	0
80 to 100	150 to 300	1	0	0
80 to 100	300 to 455	1	0	0
100	0 to 150	1	0	0
100	150 to 300	0.5	0.5	0
100	300 to 455	0	0.22	0.78

Units Units of alpacas
Definition Number of alpacas that can be fed After feeding vicunas, from the total capacity to feed southamerican camelids

The CPT was filled according this relation ship

If Total_S_C < 100 Then Alpacas_F = 0
If Vicunas_F < 100 Then Alpacas_F = 0
If Total_S_C < Vicunas_F Then Alpacas_F = 0
Else Alpacas_F = Total_S_C - Vicunas_F

Title: Fiber Vicuna Price ($/k)
Name: Price_F_V:

Restricted	No_restricted
0.99968	3.21E+01

Units $ per kilogram
Definition The price that be paided for vicuna fiber, its commercialization is restricted by CITES
Restricted 308 $/k None restricted 320 $/k
It is expect a increase in price if there are not restrictions

Title: Vicunas to cash ($/year)
Name: Vicunas_M:

Price_F_V	*Vicunas_F*	0 to 1200	1200 to 2400	2400 to 3600
Restricted	0 to 40	0.93	0.07	0
Restricted	40 to 80	0	0.75	0.25
Restricted	80 to 100	0	0	1
Restricted	100	0	0	1
No_restrcited	0 to 40	0.86	0.14	0
No_restrcited	40 to 80	0	0.67	0.33
No_restrcited	80 to 100	0	0	1
No_restrcited	100	0	0	1

Units $ per year
Definition The community sells vicuna's fiber, at fixed price, because of restrictions in commercialization by CITES.

Each vicuna produce 220 grames of fiber each two years, then at year it is around 110 gr

The CPT was filled according this relation ship
Vicunas_M = 0.11*Price_F_V*Vicunas_F

Title: Alpacas to cash ($/year)
Name: Alpacas_M:

Alpacas_F	0 to 1500	1500 to 3000	3000 to 4550
0 to 120	0.99	0.01	0
120 to 240	0	0.97	0.03
240 to 360	0	0	1

Units $ per year
Definition Similar to vicunas, alpacas also produce fiber
The fiber price is around 3.5 $/kilogram, and each alpaca produces 3.63 kg of fiber per year

The CPT was filled according this relationship
Alpacas_M = 3.6*3.5*Alpacas_F

Title: Livestock Prod ($/year)
Name: Livestock_Prod:

Vicunas_M	*Alpacas_M*	*M_Income*	0 to 13000	13000 to 26000	26000 to 39000	39000 to 52000
0 to 1200	0 to 1500	0 to 14500	0.85	0.15	0	0
0 to 1200	0 to 1500	14500 to 29000	0	0.69	0.31	0
0 to 1200	0 to 1500	29000 to 43500	0	0	0.59	0.41
0 to 1200	1500 to 3000	0 to 14500	0.68	0.32	0	0
0 to 1200	1500 to 3000	14500 to 29000	0	0.66	0.34	0
0 to 1200	1500 to 3000	29000 to 43500	0	0	0.48	0.52
0 to 1200	3000 to 4550	0 to 14500	0.63	0.37	0	0
0 to 1200	3000 to 4550	14500 to 29000	0	0.51	0.49	0
0 to 1200	3000 to 4550	29000 to 43500	0	0	0.36	0.64
1200 to 2400	0 to 1500	0 to 14500	0.71	0.29	0	0
1200 to 2400	0 to 1500	14500 to 29000	0	0.56	0.44	0
1200 to 2400	0 to 1500	29000 to 43500	0	0	0.46	0.54
1200 to 2400	1500 to 3000	0 to 14500	0.59	0.41	0	0
1200 to 2400	1500 to 3000	14500 to 29000	0	0.56	0.44	0
1200 to 2400	1500 to 3000	29000 to 43500	0	0	0.36	0.64
1200 to 2400	3000 to 4550	0 to 14500	0.49	0.51	0	0
1200 to 2400	3000 to 4550	14500 to 29000	0	0.37	0.63	0
1200 to 2400	3000 to 4550	29000 to 43500	0	0	0.24	0.76
2400 to 3600	0 to 1500	0 to 14500	0.62	0.38	0	0
2400 to 3600	0 to 1500	14500 to 29000	0	0.54	0.46	0
2400 to 3600	0 to 1500	29000 to 43500	0	0	0.45	0.55
2400 to 3600	1500 to 3000	0 to 14500	0.59	0.41	0	0
2400 to 3600	1500 to 3000	14500 to 29000	0	0.49	0.51	0
2400 to 3600	1500 to 3000	29000 to 43500	0	0	0.34	0.66
2400 to 3600	3000 to 4550	0 to 14500	0.46	0.54	0	0
2400 to 3600	3000 to 4550	14500 to 29000	0	0.31	0.69	0
2400 to 3600	3000 to 4550	29000 to 43500	0	0	0.19	0.81

Units $ per year
Definition Production from Livestock activity

Includes:
Milk Production
and Fiber Production

The CPT was filled with the equation:

Livestock_Prod = Vicunas_M + Alpacas_M + M_Income

Title: Auto Financing Capacity
Name: AutoFinanc_Capacity:

Low	High
0.5	0.5

Units Adimensional
Definition The capacity of being able to access credits and loans in a way that will not be risk for them, whitout a guarantor
The capital that they have are the land, livestock and their labour force.

Title: Training Courses
Name: Training_Courses:

PRONAMACHCS	0	0 to 12	12 to 24	24 to 36
Intervention	0	0.7	0.2	0.1
No	1	0	0	0

Units Number of training courses given
Defintion Courses given by PRONAMACHCS including field training.

The CPT was filled according the data from the report:
Assesment of successful cases in the Scope of Peru-Sierra
Natural Resources Management and Poverty Alleviation Project

Title: Labor Contribution (day/week)
Name: Labor_Contribution:

Low	Medium	High
0.6	0.3	0.1

Units days per week of free labor by campesino
Definition How many days a campesino will work in the activities of soil conservation, land management, milk production.
The CPT was filled base on
Assesment of successful cases in the Scope of Peru-Sierra
Natural Resources Management and Poverty Alleviation Project

Title: Beneficiaries
Name: Beneficiaries:

10 to 40	40 to 70	70 to 100
0.7	0.1	0.2

Units Percentaje of Beneficiaries
Definition People that get direct or indirect benefits thorugh the Project activities

The estimation is based in the report of:
Assesment of successful cases in the Scope of Peru-Sierra
Natural Resources Management and Poverty Alleviation Project

Title: Participation
Name: Participation:

Beneficiaries	*Labor Contribution*	Low	Medium	High
10 to 40	Low	1	0	0
10 to 40	Medium	0.5	0.47	0.03
10 to 40	High	0.5	0.4	0.1
40 to 70	Low	0.68	0.31	0.01
40 to 70	Medium	0.2	0.74	0.06
40 to 70	High	0.2	0.6	0.2
70 to 100	Low	0.6	0.35	0.05
70 to 100	Medium	0	0.3	0.7
70 to 100	High	0	0	1

Units Adimensional
Definition How active is the people of the community in watershed management activities
This will be measured trough the percentage of beneficiaries, and the Labor Contribution
Because them are indicators of the interest of people in be involved
The CPT was filled according the authors beliefs

Title: Attendance (%)
Name: Attendance1:

Low [0-30%]	High [30 - 70]
0.1	0.9

Units Percentage of assitance
Definition % of persons from the total population that assit to Training Courses
3 per family => 3/4 = 0.75
The estimation is based in the report of:
Assesment of successful cases in the Scope of Peru-Sierra
Natural Resources Management and Poverty Alleviation Project

Title: Technical Capacity
Name: Tech_Capacity1:

Training_ Courses	*Attendance1*	High	Low
0	Low	0.15	0.85
0	High	0.15	0.85
0 to 12	Low	0.2	0.8
0 to 12	High	0.6	0.4
12 to 24	Low	0.35	0.65
12 to 24	High	0.8	0.2
24 to 36	Low	0.4	0.6
24 to 36	High	1	0

Units Adimensional
Definition It is the technical knowledge related to land use land management, building of soil conservation structures, maintenance, operation of sprinkler system irrigation, and activities involved in the management of the watershed.

According the author beliefs, the andean communities because of their indeginous knowledge of land management, even they don't receive training courses they have certain Technical capacity.

Title: Total Capacity
Name: Total_Cap:

Tech_ Capacity1	*Labor_Contr*	High	Low
High	Low	0.6	0.4
High	Medium	0.7	0.3
High	High	0.8	0.2
Low	Low	0.1	0.9
Low	Medium	0.2	0.8
Low	High	0.25	0.75

Units adimensional
Definition It represents the technical capacity, and the labor available to realize activities of watershed management, in other words, not only know how to do it, also, who is going to do it.

Title: **Agr. Inputs Provision**
Name: **Agric_Inputs:**

Units: Adimensional
Definition: Provision of Agriculture inputs like seeds, fertilizers and pesticides.

AutoFinanc_Capacity	PRONAMACHCS	Low	High
Low	Intervention	0.2	0.8
Low	No	0.9	0.1
High	Intervention	0	1
High	No	0	1

One of the main tasks of PRONAMACHCS is providing seeds to Ayas Community

Title: **Yield Improvement**
Name: **Yield_Improve:**

Units: Adimensional
Definition: Represents the variation in the yield of agriculture production in base of the improvements of the previous yield because the intervention of PRONAMACHCS

Agric_Inputs	*Tech_ Capacity1*	*Rainfall*	Dimish	Same	Improve
Low	High	0 to 600	0.85	0.1	0.05
Low	High	600 to 750	0.7	0.25	0.05
Low	High	750 to 900	0.55	0.4	0.05
Low	Low	0 to 600	0.95	0.05	0
Low	Low	600 to 750	0.8	0.2	0
Low	Low	750 to 900	0.7	0.3	0
High	High	0 to 600	0.6	0.35	0.05
High	High	600 to 750	0.1	0.3	0.6
High	High	750 to 900	0.05	0.2	0.75
High	Low	0 to 600	0.6	0.3	0.1
High	Low	600 to 750	0.5	0.35	0.15
High	Low	750 to 900	0.45	0.4	0.15

Variations in yield are function of rainfall, agriculture inputs and Technical capacity

The uncontrolable one is rainfall

Title: **Agric. Productivity ($/ha)**
Name: **Agric_Prod1:**

Units: U.S. $ per hectar
Definition: Net Income from Agriculture production per hectar
The actual productivity, computed base on the actual yields is around = 520 $/hectar
With previous yields around 300 $/hectar, and with maximum yields are more than 750 $/hectar

Yield_Improve	300	520	750
Dimish	0.8	0.15	0.05
Same	0.15	0.8	0.05
Improve	0.05	0.15	0.8

Title: **Cultivated Area**
Name: **Cultivated_Area:**

Units: Hectares
Definition: Land used for agriculture production. Even there is more available land for agriculture, at present only 36 hectares have being working properly. According reports, the area can extend at least 10 hectares in one or two years.

26	36	46	56
0.07	0.85	0.04	0.04

Title: **Agriculture Prod ($/year)**
Name: **Agric_Prod2**

Units: $ per year
Definition: Production from agriculture activity of the land cultivated considering only the income from the commercialized crops

Agric_Prod1	*Cultivated _Area*	Agric_Prod2
300	26	0 to 15000
300	36	0 to 15000
300	46	0 to 15000
300	56	15000 to 30000
520	26	0 to 15000
520	36	15000 to 30000
520	46	15000 to 30000
520	56	15000 to 30000
750	26	15000 to 30000
750	36	15000 to 30000
750	46	30000 to 42000
750	56	30000 to 42000

The CPT was filled according this relation ship

Agric_Prod2 = Agric_Prod1*Cultivated_Area

Title: Total Production ($/year)
Name: Total_Production:

Agric_Prod2	*Livestock _Prod*	0 to 23500	23500 to 47000	47000 to 70500	70500 to 94000
0 to 15000	0 to 13000	0.91	0.09	0	0
0 to 15000	13000 to 26000	0.34	0.66	0	0
0 to 15000	26000 to 39000	0	0.92	0.08	0
0 to 15000	39000 to 52000	0	0.11	0.89	0
15000 to 30000	0 to 13000	0.12	0.88	0	0
15000 to 30000	13000 to 26000	0	0.81	0.19	0
15000 to 30000	26000 to 39000	0	0.06	0.94	0
15000 to 30000	39000 to 52000	0	0	0.71	0.29
30000 to 42000	0 to 13000	0	0.82	0.18	0
30000 to 42000	13000 to 26000	0	0.06	0.94	0
30000 to 42000	26000 to 39000	0	0	0.63	0.37
30000 to 42000	39000 to 52000	0	0	0.01	0.99

Units $/year
Definition Total production in one year from the mean productivity activities of the community as: Livestock, and agriculture

The CPT was filled according this relation ship

Total_Production = Agric_Prod2 + Livestock_Prod

Title: Total Benefits ($/year)
Name: Total_Benefits:

Total_Production	0 to 15000	15000 to 30000	30000 to 45000	45000 to 60000	60000 to 75000	75000 to 84000
0 to 23500	0.72	0.28	0	0	0	0
23500 to 47000	0	0.42	0.58	0	0	0
47000 to 70500	0	0	0.17	0.71	0.12	0
70500 to 94000	0	0	0	0	0.63	0.37

Units $ per year
Definition Means the net Benefits of Ayas Community.
It represents about 89% of the Total Production
Approach based on Table 3.3

The CPT was filled with this equation:
Total Benefits = 0.89*Total_Production

Title: Income ($/capita/year)
Name: Income_P:

Income per capita per year
Total population = 122

Total_ Benefits	0 to 100	100 to 200	200 to 300	300 to 400	400 to 500	500 to 600	600 to 700
0 to 15000	0.81	0.19	0	0	0	0	0
15000 to 30000	0	0.65	0.35	0	0	0	0
30000 to 45000	0	0	0.48	0.52	0	0	0
45000 to 60000	0	0	0	0.21	0.79	0	0
60000 to 75000	0	0	0	0	0.09	0.81	0.1
75000 to 84000	0	0	0	0	0	0	1

Income_P (Total_Benefits) = (Total_Benefits/122)

Title: Sustainability
Name: Sustainability:

Income_P	*Labor_ Contribution*	Low	High
0 to 100	Low	0.95	0.05
0 to 100	Medium	0.9	0.1
0 to 100	High	0.85	0.15
100 to 200	Low	0.8	0.2
100 to 200	Medium	0.75	0.25
100 to 200	High	0.7	0.3
200 to 300	Low	0.65	0.35
200 to 300	Medium	0.6	0.4
200 to 300	High	0.56	0.44
300 to 400	Low	0.55	0.45
300 to 400	Medium	0.52	0.48
300 to 400	High	0.5	0.5
400 to 500	Low	0.4	0.6
400 to 500	Medium	0.35	0.65
400 to 500	High	0.3	0.7
500 to 600	Low	0.25	0.75
500 to 600	Medium	0.2	0.8
500 to 600	High	0.15	0.85
600 to 700	Low	0.2	0.8
600 to 700	Medium	0.1	0.9
600 to 700	High	0.05	0.95

Units Adimensional
Definition Sustainability, in sense of the Project Peru-Sierra Natural Resourcese Management...
According World Bank and PRONAMACHCS hypothesis (World Bank 1996), the sustainability of the project is based on the participation of community, overall trough labour.
Because of Project;s objective is poverty alleviation, income eas defyned as a indicator of poverty level in this study
This Variable don not qualify natural sustainability because there is not enough information to deal with this, and with the available data, include this aspect in the Network will complicated very much the understanding of the system.

SUSTAINABLE IN ACHIEVE THE OBJECTIVE OF POVERTY ALLEVIATION

Title: Management Capacity
Name: Manag_Capacity:

Participation	*Tech_ Capacity1*	**Strong**	**Weak**
Low	High	0.3	0.7
Low	Low	0	1
Medium	High	0.6	0.4
Medium	Low	0.24	0.76
High	High	1	0
High	Low	0.4	0.6

Units Adimensional
Definition It means the capacity of the community to manage by themselves the watershed.
This means, they have enough knowledge, in technic and administrative issues.
According the approach of the Project, PRONAMACHCS and World Bank, the key activities to achive this, are Participation and Technical Capacity

The CPT was filled according the author beliefes given more weight for the Technical capacity.

Title: Autonomy
Name: Autonomy:

Manag_ Capacity	*AutoFinanc _Capacity*	**Low**	**Enough**
Strenght	Low	0.6	0.4
Strenght	High	0.05	0.95
Weak	Low	0.9	0.1
Weak	High	0.55	0.45

Units Adimensional
Definition Autonomy to manage the watershed by themselves without the guidance of PRONAMACHCS or other Institution. Capacity of find their own financial resources, improve their knowledge.

According the author beliefs, autnonomy will depend of the grade of Management Capacity and Autofinancing capacity.

CPT – Consult to the specialist, this case D.r Batchelor

Batchelor CPT (original)

Catchement area	Rainfall mm/year	Increase Qspring in dry season (%)			
		0 - 10	10 - 30	30 - 60	60 - 100
0 - 25	0-600	***90***	***10***	***0***	***0***
0 - 25	*600-750*	***85***	***15***	***0***	***0***
0 - 25	750-900	***80***	***15***	***5***	***0***
25 - 50	0-600	***70***	***15***	***15***	***0***
25 - 50	600-750	***65***	***30***	***5***	***0***
25 - 50	750-900	***60***	***30***	***10***	***5***
50 - 75	0-600	***50***	***25***	***5***	***0***
50 - 75	600-750	***45***	***45***	***10***	***5***
50 - 75	750-900	***40***	***40***	***15***	***10***
75 - 100	0-600	***30***	***35***	***15***	***5***
75 - 100	600-750	***25***	***50***	***20***	***10***
75 - 100	750-900	***20***	***45***	***25***	***15***

<= Ranges

Rainfall (mm/year)	Infiltration %	Infiltration mm/year	*0-10*	*10-30*	*30-60*	*60-100*	
			5	20	45	80	
0-600	1.7	5	5.25	6	7.25	9	
600-750	5.2	35	36.75	42	50.75	63	
750-900	10.3	85	89.25	102	123.25	153	

<= Ranges of Increse Qs
<= Class Mark of Increse Qs
Increasing Qspring in mm/year

Treated Area (%)	Rainfall (mm/year)	Infiltration in mm/year		
		0 - 10	10 - 50	> 50
		5	*30*	*100*
0-25	0-600	100	0	0
0-25	600-750	0	90	10
0-25	750-900	0	0	100
25-50	0-600	100	0	0
25-50	600-750	0	95	5
25-50	750-900	0	0	100
50-75	0-600	100	0	0
50-75	600-750	0	90	10
50-75	750-900	0	0	100
75-100	0-600	100	0	0
75-100	600-750	0	75	25
75-100	750-900	0	0	100

<= Ranges of Infiltration
<= Class Mark of Infiltration

$Area_{spring}$	1000	ha	
Crop Req	500	mm/year	
Efficiency	0.7	0.6	
	Sprinkler	No Sprink	

Infiltration mm	Vol m^3/yr	Area ha irrig	
5	50000	7	6 [Low]
30	300000	42	36 [Medium]
100	1000000	140	120 [High]

Finally, comparing this table with the above table, it is possible get the percentages for different combination of statements.

Treated Area (%)	Rainfall (mm/year)	Available Water m^3/year		
		50000	300000	1000000
0-25	0-600	100	0	0
0-25	600-750	0	90	10
0-25	750-900	0	0	100
25-50	0-600	100	0	0
25-50	600-750	0	95	5
25-50	750-900	0	0	100
50-75	0-600	100	0	0
50-75	600-750	0	90	10
50-75	750-900	0	0	100
75-100	0-600	100	0	0
75-100	600-750	0	75	25
75-100	750-900	0	0	100

			from:	to:
To irrigate	20 ha	need	142857	166667 m^3/yr
	30 ha	need	214286	250000 m^3/yr

Calculation of Milk production

Relationship establish according field data from AYAS

yield <=	If irrigation is effective
21500 kg/ha	grass (per year)

Note: Yield reduction because water stress in grass is minimun and depend of the growing state

Total area
20 ha

Total Production
430000 kg

		Milk Production/cow		Milk Production
	Nro animals	lt/ordeño	ordeño/day	lt/year
Productive	20	9	2	131400
Non Product	30	0	0	

Estimation fo cattle

Sefun FARMOD:	**Total population**	137

After Social Agroeconomic Diagnosis, 1999

	Units	%	=> Estimating de 137:		But ther is a know value	
Cows (milk)	9	0.19	26		20	
Cows	18	0.38	52	=>	58	
Bulls	9	0.19	26		26	84
veal (ternera)	8	0.17	23		23	
calf (ternero)	3	0.06	9		10	33
	47				137	

ESTIMATION OF GRASS CONSUPTION FOT CATTLES.

- Vacas en produccion de Leche

After: Recomendaciones para la alimentacion de las vacas lecheras. Beth Wheeler
http://www.engormix.com/nuevo/prueba/areadeganaderialeche1.asp?valor=104

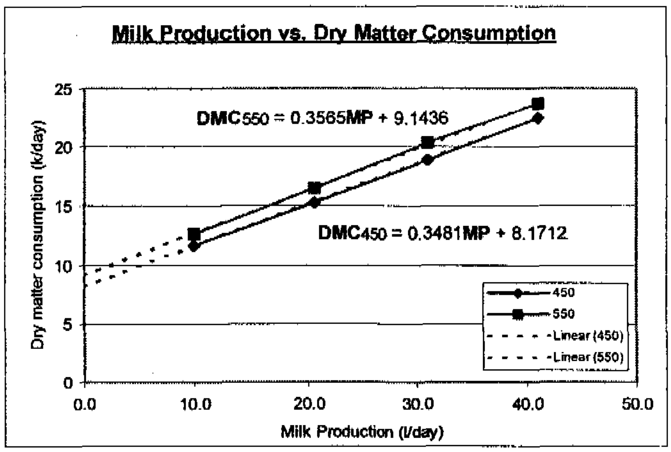
Milk Production l/day/cow	Dry matter Cons k/day	
	450	550
10.0	11.7	12.7
20.6	15.3	16.5
31.0	18.9	20.4
41.0	22.5	23.7

Enter value

8.5	11.1	12.2

Nro cows: 20

Milk Prod	**DMC**
l/day	k/day
170	222.6
	Total



From Ayas reports — Current Situation

Actual grass yield k/ha		21500 /year							
Total grass area	ha	20							
Total grass prod.	k/year	430000			N_{cows}	DMC_{cows}	N_{other}	DMC_{other}	
	k/day	1178	=	1178	20	11.1	117	8.17	

$$TGP = N_{cows} \times DMC_{cows} + N_{other} \times DMC_{other} \quad (1)$$

Milk Prod	l/day/cow	8.5
=> DMC_{cows} *	k/day	11.1
=> DMC_{others} **	k/day	8.2

=> DMC_{cows} = 1.36 DMC_{other} (2)
DMC_{other} = 0.73 DMC_{cows}

* Suppossing weight of 450 kilograms

** from (2)

Assuming there is not variation in the cattle population

	TGP =	105.88 **DMC**		[k/day]		
	DMC =	0.35 **MP** +	8.17	[k/day]	*From the graph*	
	TGP =	36.86 **MP** +	865	[k/day]	(1)	
	TGP =	58.90 **Grassland**		[k/day]	(2)	
From (1)=(2)	**MP** =	1.60 **Grassland** -	23.47	[l/day]	Only for Grassland >	14.69 ha

Area ha	TGP k/day	Cows unit	Others unit	DMC_{cows} k/day/cow	Milk Prod l/day/cow		
3.5	206.164	20	117	1.9	-17.9	-17.87	No valuables valu
5.3	312.192	20	117	2.9	-15.1	-14.99	No valuables valu
12	706.849	20	117	6.6	-4.4	-4.27	No valuables valu
15	883.562	20	117	8.3	0.3	0.53	
17	1001.37	20	117	9.4	3.5	3.73	Milk production before
20	1178.08	20	117	11.1	8.3	8.53	Milk production now
30	1767.12	20	117	16.6	24.2		

Annex III: Sensitivity Analysis Results

1 Tables

Scenary 1

Node	Income Variance Reduction	Income Qadratic Score
Yield_Improve	1820	0.0033031
Irrig_G_Area	1393	0.0021012
Rainfall	873.5	0.0011613
Cultivated_Area	281.2	0.0003899
Total_S_C	80.9	0.0000939
Attendance1	10.87	0.0000156
Labor_Contribution	0.2052	0.0000002
Total_FI_Area	0.1799	0.0000002
Beneficiaries	0	0
PRONAMACHCS	0	0

Node	Sustainability Mutual Info	Sustainability Quadratic Score
Yield_Improve	0.01086	0.0033436
Irrig_G_Area	0.00791	0.0025032
Rainfall	0.00519	0.0015908
Labor_Contribution	0.00291	0.0009146
Cultivated_Area	0.00163	0.0005115
Total_S_C	0.00067	0.000208
Attendance1	0.00006	0.0000199
Total_FI_Area	0	0.0000003
Beneficiaries	0	0
PRONAMACHCS	0	0

Node	Autonomy Mutual Info	Autonomy Quadratic Score
Labor_Contribution	0.00478	0.0015932
Yield_Improve	0.00457	0.0015175
Beneficiaries	0.00377	0.0012653
Total_S_C	0.00153	0.000508
Attendance1	0.00094	0.0003073
Rainfall	0	0
Irrig_G_Area	0	0
Total_FI_Area	0	0
Cultivated_Area	0	0
PRONAMACHCS	0	0

Node	Manag Capacity Mutual Info	Manag Capacity Quadratic Score
Labor_Contribution	0.03337	0.0099573
Beneficiaries	0.02568	0.0079084
Total_S_C	0.01071	0.0031747
Yield_Improve	0.00971	0.002897
Attendance1	0.00716	0.0019205
Cultivated_Area	0	0
PRONAMACHCS	0	0
Total_FI_Area	0	0
Rainfall	0	0
Irrig_G_Area	0	0

Scenary 2

Node	Income Variance Reduction	Income Qadratic Score
Yield_Improve	1324	0.0023348
Irrig_G_Area	982.4	0.0014771
Rainfall	461.5	0.0007524
Cultivated_Area	281.2	0.0004382
Total_S_C	46.48	0.0000767
Labor_Contribution	0.183	0.0000003
Total_FI_Area	0.1616	0.0000003
PRONAMACHCS	0	0
Beneficiaries	0	0
Attendance1	0	0

Node	Sustainability Mutual Info	Sustainability Quadratic Score
Yield_Improve	0.00809	0.0024408
Irrig_G_Area	0.0057	0.0017691
Labor_Contribution	0.00309	0.000934
Rainfall	0.00287	0.0008431
Cultivated_Area	0.0017	0.0005171
Total_S_C	0.00045	0.0001355
Total_FI_Area	0	0.0000003
PRONAMACHCS	0	0
Attendance1	0	0
Beneficiaries	0	0

Node	Autonomy Mutual Info	Autonomy Quadratic Score
Yield_Improve	0.01761	0.0055943
Labor_Contribution	0.00343	0.0010598
Beneficiaries	0.00247	0.0007686
Total_S_C	0.00074	0.0002287
PRONAMACHCS	0	0
Attendance1	0	0
Cultivated_Area	0	0
Total_FI_Area	0	0
Rainfall	0	0
Irrig_G_Area	0	0

Node	Manag Capacity Mutual Info	Manag Capacity Quadratic Score
Labor_Contribution	0.03863	0.006624
Beneficiaries	0.02574	0.0048038
Total_S_C	0.0078	0.0014294
Yield_Improve	0.00468	0.0008829
Attendance1	0	0
Cultivated_Area	0	0
PRONAMACHCS	0	0
Total_FI_Area	0	0
Rainfall	0	0
Irrig_G_Area	0	0

Scenary 3

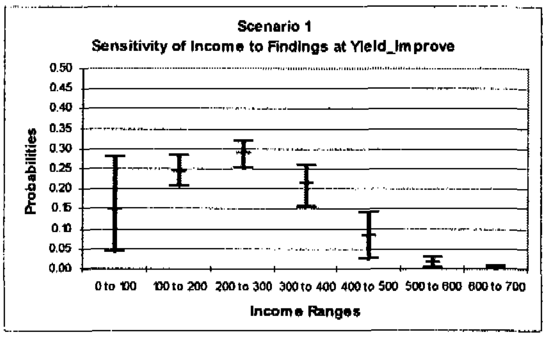
Node	Income: Variance Reduction	Income: Qadratic Score	Node	Sustainability: Mutual Info	Sustainability: Quadratic Score	Node	Autonomy: Mutual Info	Autonomy: Quadratic Score	Node	Manag Capacity: Mutual Info	Manag Capacity: Quadratic Score
Rainfall	8158	0.0081953	Rainfall	0.0433	0.0145024	Labor_Contribution	0.00478	0.0015932	Labor_Contribution	0.03337	0.0099573
Irrig_G_Area	8154	0.0081883	Irrig_G_Area	0.04327	0.0144947	Yield_Improve	0.00457	0.0015175	Beneficiaries	0.02568	0.0079084
Yield_Improve	4463	0.0045836	Yield_Improve	0.0232	0.0079142	Beneficiaries	0.00377	0.0012653	Total_S_C	0.01302	0.0038758
Cultivated_Area	291	0.0001643	Labor_Contribution	0.00287	0.0009881	Total_S_C	0.00186	0.0006201	Yield_Improve	0.00971	0.002897
Total_S_C	110.5	0.0000979	Cultivated_Area	0.00148	0.0005108	Attendance1	0.00094	0.0003073	Attendance1	0.00716	0.0019205
Attendance1	11.27	0.0000128	Total_S_C	0.00079	0.0002727	Rainfall	0	0	Cultivated_Area	0	0
Labor_Contribution	0.3712	0.0000003	Attendance1	0.00006	0.0000196	Irrig_G_Area	0	0	PRONAMACHCS	0	0
Total_Fl_Area	0	0	Total_Fl_Area	0	0	Total_Fl_Area	0	0	Total_Fl_Area	0	0
Beneficiaries	0	0	Beneficiaries	0	0	Cultivated_Area	0	0	Rainfall	0	0
PRONAMACHCS	0	0	PRONAMACHCS	0	0	PRONAMACHCS	0	0	Irrig_G_Area	0	0

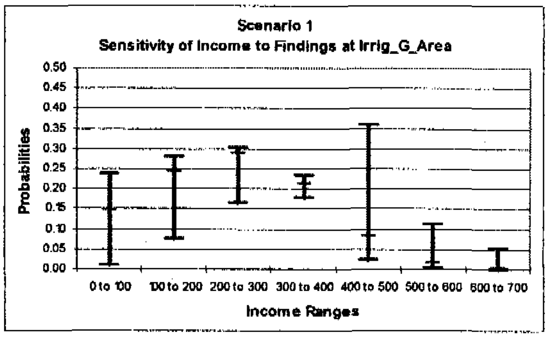
Scenary 4

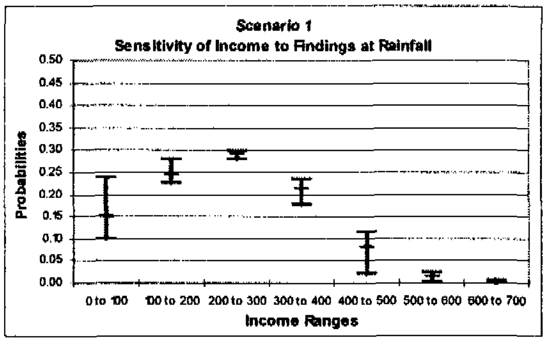
Node	Income: Variance Reduction	Income: Qadratic Score	Node	Sustainability: Mutual Info	Sustainability: Quadratic Score	Node	Autonomy: Mutual Info	Autonomy: Quadratic Score	Node	Manag Capacity: Mutual Info	Manag Capacity: Quadratic Score
Rainfall	6764	0.0070545	Rainfall	0.03673	0.0121071	Yield_Improve	0.01761	0.0055943	Labor_Contribution	0.03863	0.006624
Irrig_G_Area	6761	0.0070466	Irrig_G_Area	0.03671	0.0121006	Labor_Contribution	0.00343	0.0010598	Beneficiaries	0.02574	0.0048038
Yield_Improve	2218	0.0020777	Yield_Improve	0.01156	0.0039394	Beneficiaries	0.00247	0.0007686	Total_S_C	0.00967	0.0017768
Cultivated_Area	273	0.0001608	Labor_Contribution	0.00283	0.0009647	Total_S_C	0.00092	0.0002843	Yield_Improve	0.00468	0.0008829
Total_S_C	70.39	0.0000727	Cultivated_Area	0.00142	0.0004838	Rainfall	0	0	Attendance1	0	0
Labor_Contribution	0.3679	0.0000004	Total_S_C	0.00056	0.0001918	Total_Fl_Area	0	0	Cultivated_Area	0	0
Attendance1	0	0	Beneficiaries	0	0	Irrig_G_Area	0	0	PRONAMACHCS	0	0
Total_Fl_Area	0	0	Total_Fl_Area	0	0	Cultivated_Area	0	0	Total_Fl_Area	0	0
Beneficiaries	0	0	Attendance1	0	0	PRONAMACHCS	0	0	Rainfall	0	0
PRONAMACHCS	0	0	PRONAMACHCS	0	0	Attendance1	0	0	Irrig_G_Area	0	0

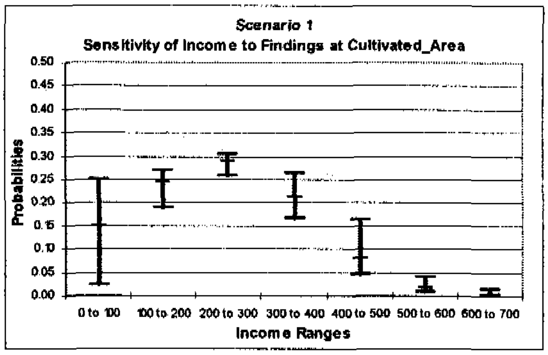
2 Graphics

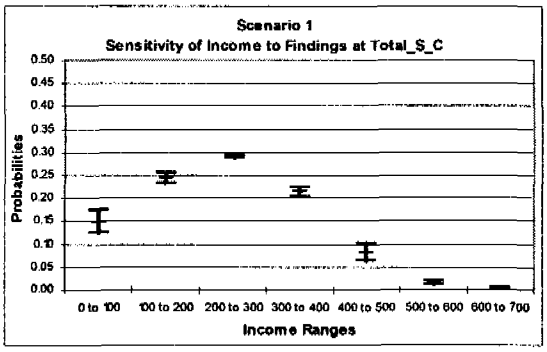
2.1 Income

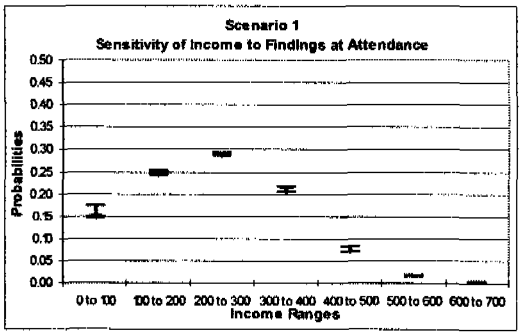


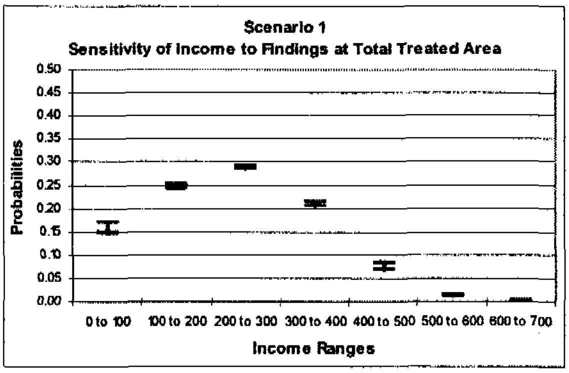


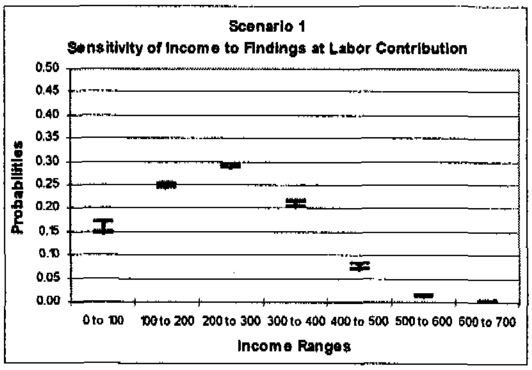


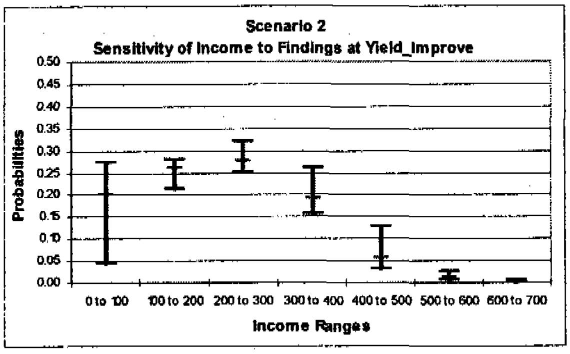


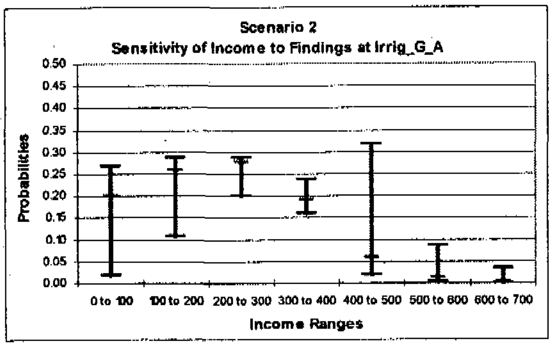


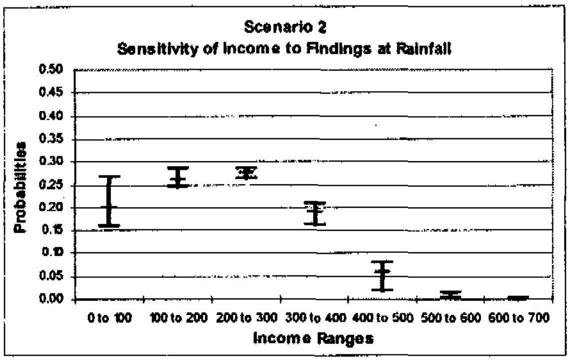


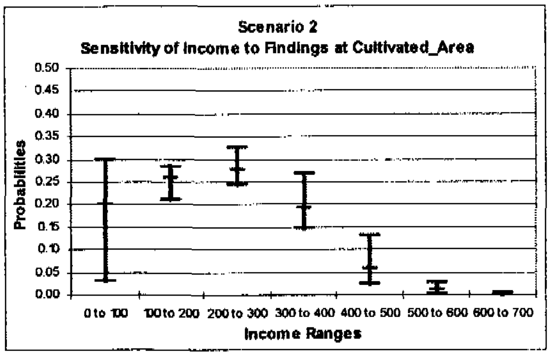


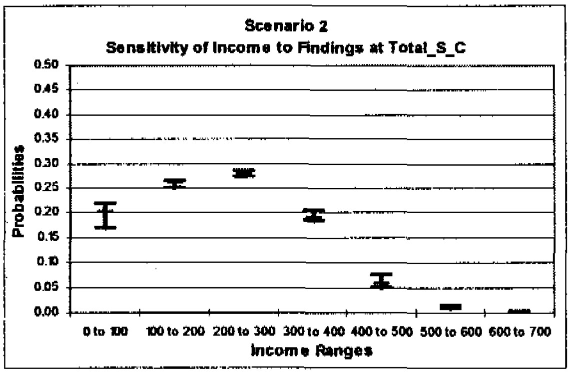


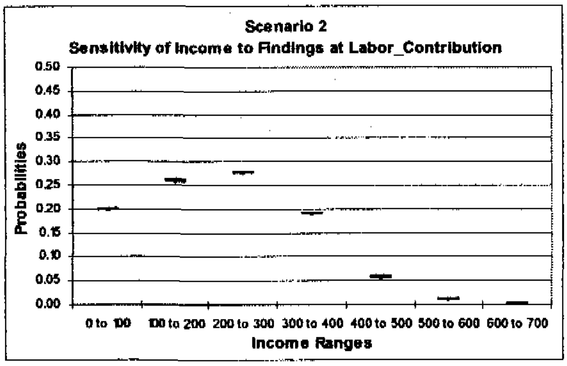

Scenario 2
Sensitivity of Income to Findings at Yield_Improve
Probabilities
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
0 to 100 100 to 200 200 to 300 300 to 400 400 to 500 500 to 600 600 to 700
Income Ranges


Scenario 2
Sensitivity of Income to Findings at Irrig_G_A
Probabilities
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
0 to 100 100 to 200 200 to 300 300 to 400 400 to 500 500 to 600 600 to 700
Income Ranges


Scenario 2
Sensitivity of Income to Findings at Rainfall
Probabilities
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
0 to 100 100 to 200 200 to 300 300 to 400 400 to 500 500 to 600 600 to 700
Income Ranges


Scenario 2
Sensitivity of Income to Findings at Cultivated_Area
Probabilities
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
0 to 100 100 to 200 200 to 300 300 to 400 400 to 500 500 to 600 600 to 700
Income Ranges


Scenario 2
Sensitivity of Income to Findings at Total_S_C
Probabilities
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
0 to 100 100 to 200 200 to 300 300 to 400 400 to 500 500 to 600 600 to 700
Income Ranges


Scenario 2
Sensitivity of Income to Findings at Labor_Contribution
Probabilities
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
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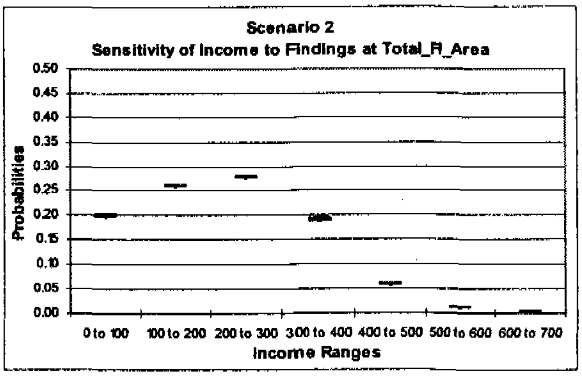
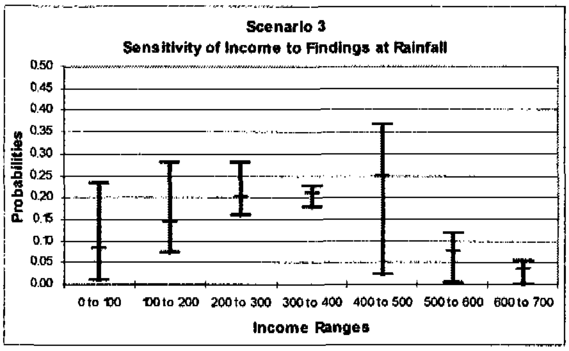
Income Ranges


Scenario 2
Sensitivity of Income to Findings at Total_R_Area
Probabilities
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
0 to 100 100 to 200 200 to 300 300 to 400 400 to 500 500 to 600 600 to 700
Income Ranges


Scenario 3
Sensitivity of Income to Findings at Rainfall
Probabilities
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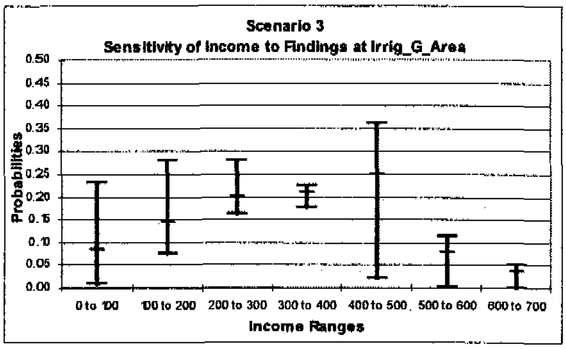
100 to 200
200 to 300
300 to 400
400 to 500
500 to 600
600 to 700
Income Ranges


Scenario 3
Sensitivity of Income to Findings at Irrig_G_Area
Probabilities
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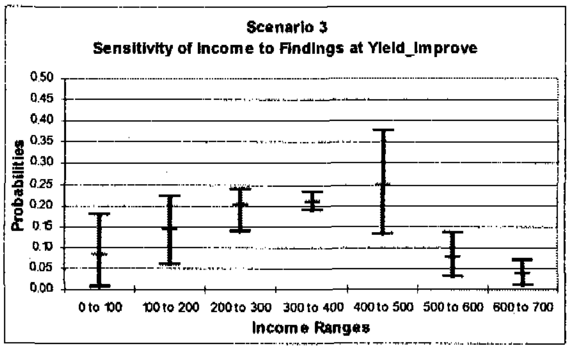
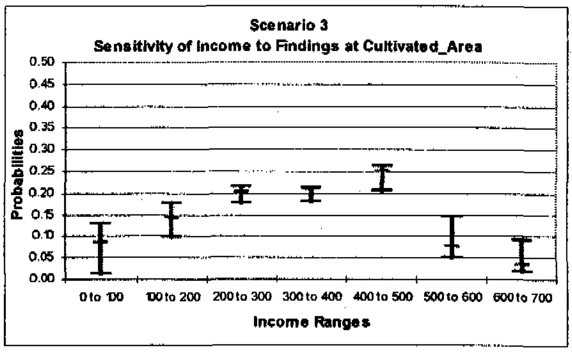
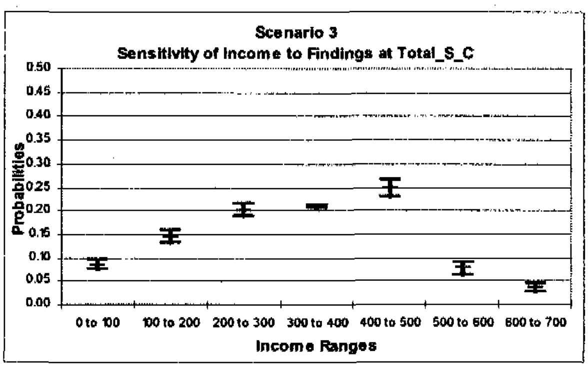
100 to 200
200 to 300
300 to 400
400 to 500
500 to 600
600 to 700
Income Ranges


Scenario 3
Sensitivity of Income to Findings at Yield_Improve
Probabilities
0 to 100
100 to 200
200 to 300
300 to 400
400 to 500
500 to 600
600 to 700
Income Ranges


Scenario 3
Sensitivity of Income to Findings at Cultivated_Area
Probabilities
0 to 100
100 to 200
200 to 300
300 to 400
400 to 500
500 to 600
600 to 700
Income Ranges


Scenario 3
Sensitivity of Income to Findings at Total_S_C
Probabilities
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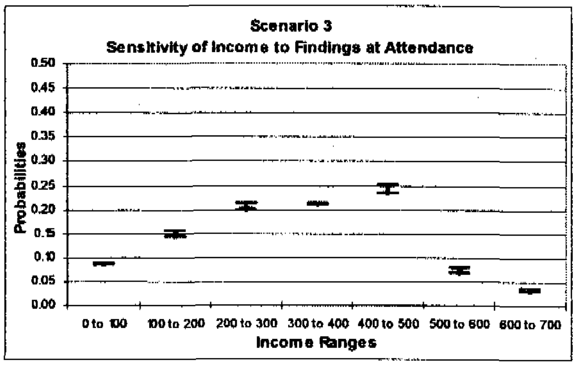
100 to 200
200 to 300
300 to 400
400 to 500
500 to 600
600 to 700
Income Ranges


Scenario 3
Sensitivity of Income to Findings at Attendance
Probabilities
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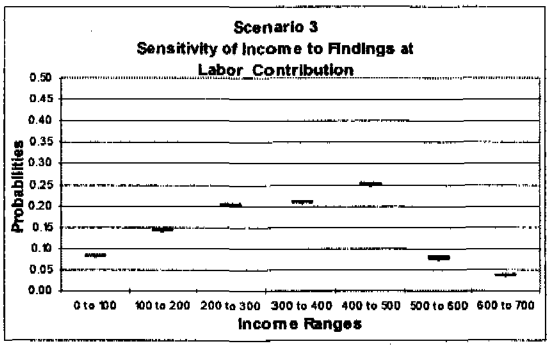
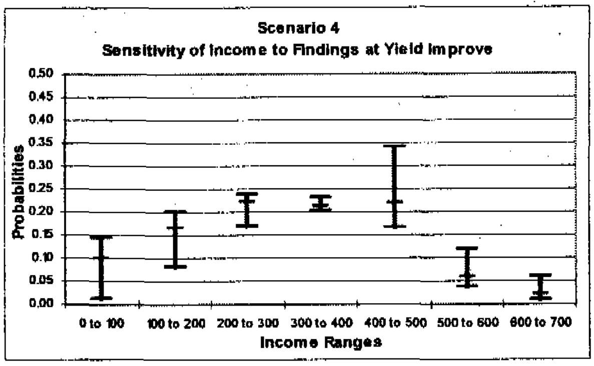
100 to 200
200 to 300
300 to 400
400 to 500
500 to 600
600 to 700
Income Ranges


Scenario 3
Sensitivity of Income to Findings at
Labor_Contribution
Probabilities
0 to 100
100 to 200
200 to 300
300 to 400
400 to 500
500 to 600
600 to 700
Income Ranges


Scenario 4
Sensitivity of Income to Findings at Yield Improve
Probabilities
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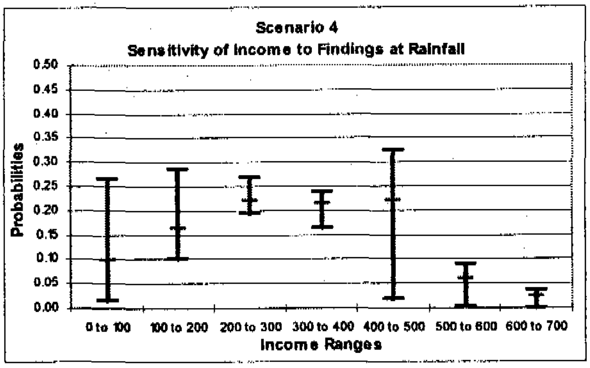
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0 to 100
100 to 200
200 to 300
300 to 400
400 to 500
500 to 600
600 to 700
Income Ranges


Scenario 4
Sensitivity of Income to Findings at Rainfall
Probabilities
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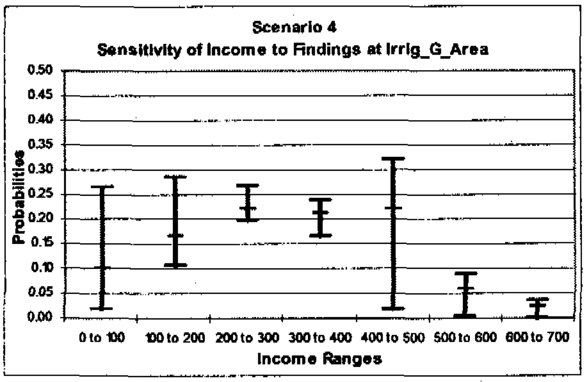
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0 to 100
100 to 200
200 to 300
300 to 400
400 to 500
500 to 600
600 to 700
Income Ranges


Scenario 4
Sensitivity of Income to Findings at Irrig_G_Area
Probabilities
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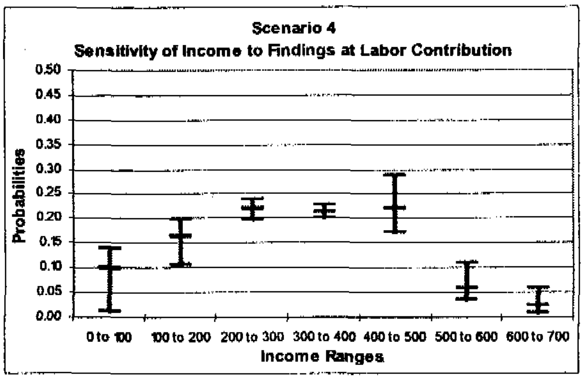
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0 to 100
100 to 200
200 to 300
300 to 400
400 to 500
500 to 600
600 to 700
Income Ranges


Scenario 4
Sensitivity of Income to Findings at Labor Contribution
Probabilities
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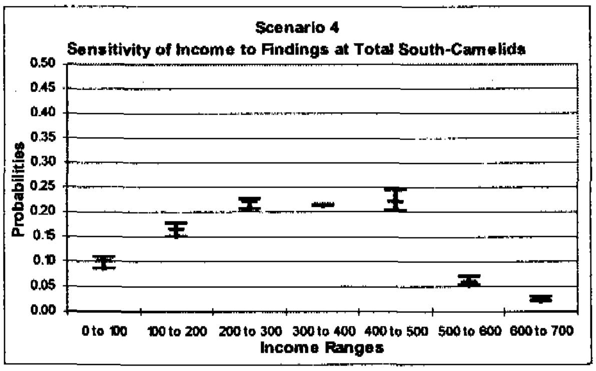
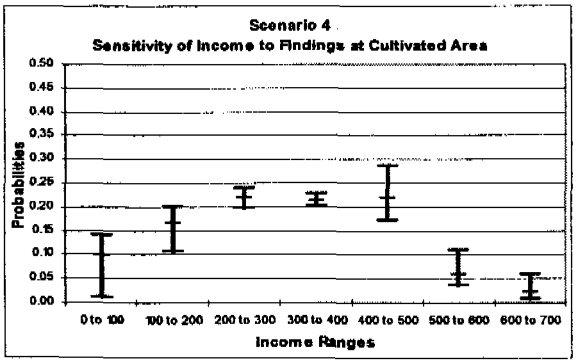
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0 to 100
100 to 200
200 to 300
300 to 400
400 to 500
500 to 600
600 to 700
Income Ranges


Scenario 4
Sensitivity of Income to Findings at Total South-Camelids
Probabilities
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0 to 100
100 to 200
200 to 300
300 to 400
400 to 500
500 to 600
600 to 700
Income Ranges


Scenario 4
Sensitivity of Income to Findings at Cultivated Area
Probabilities
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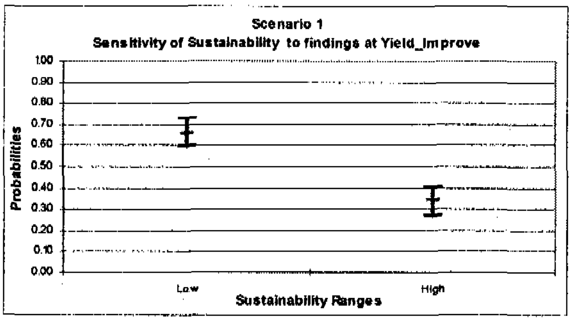
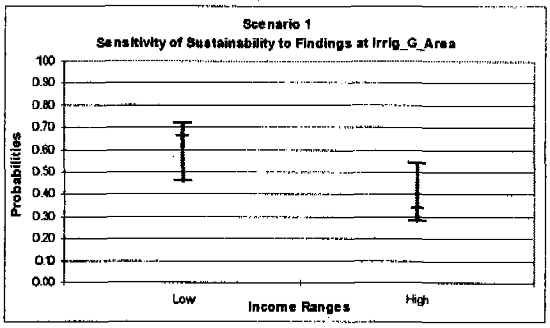
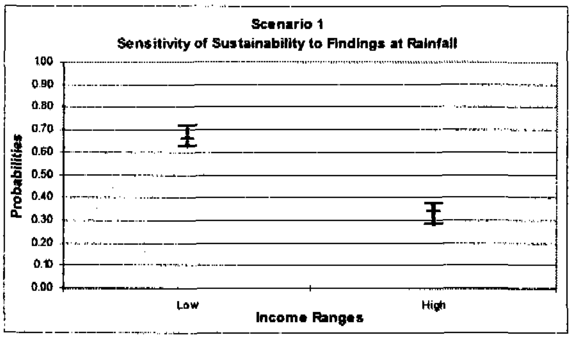
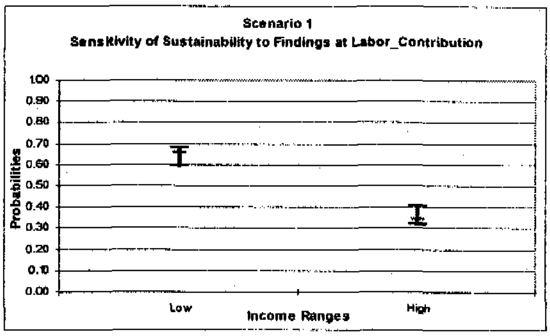
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0 to 100
100 to 200
200 to 300
300 to 400
400 to 500
500 to 600
600 to 700
Income Ranges

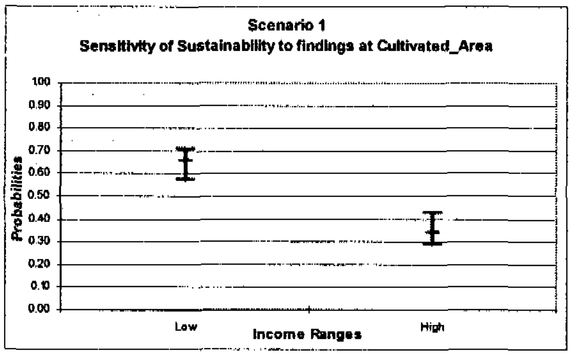
2.2 Sustainability

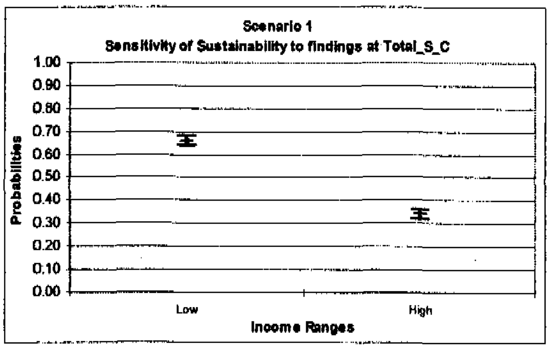


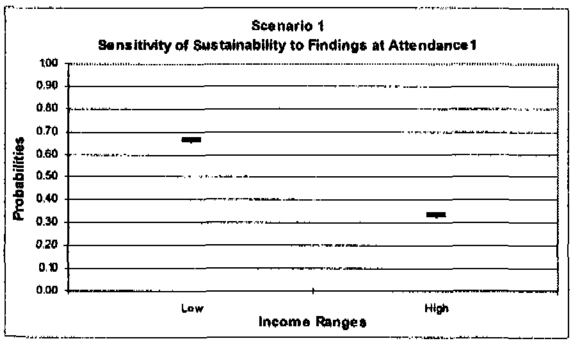


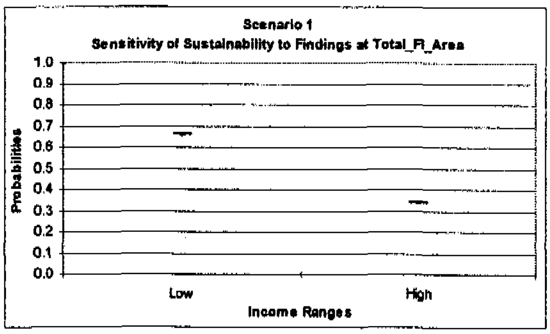


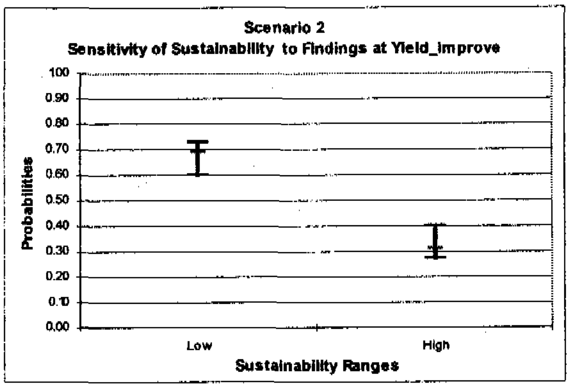


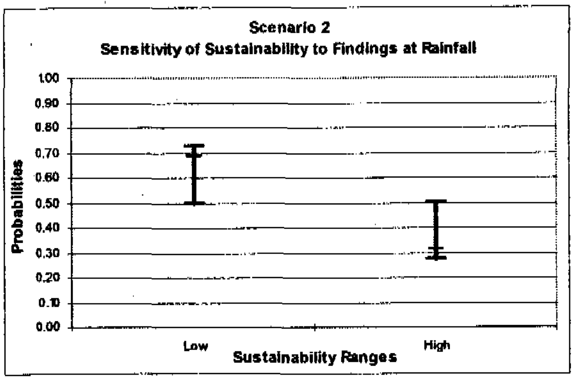


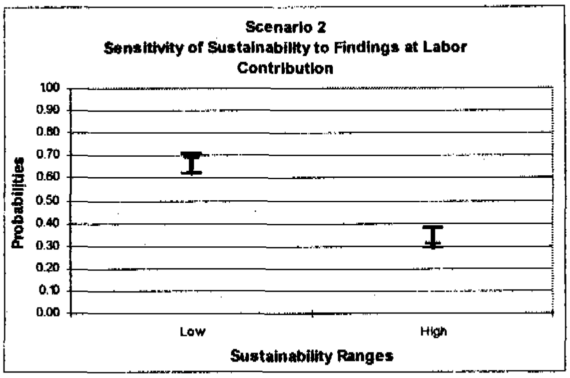


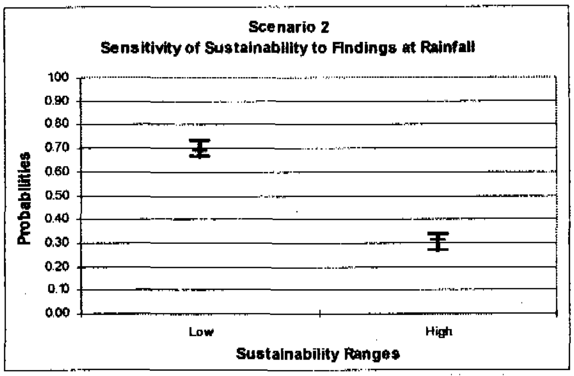


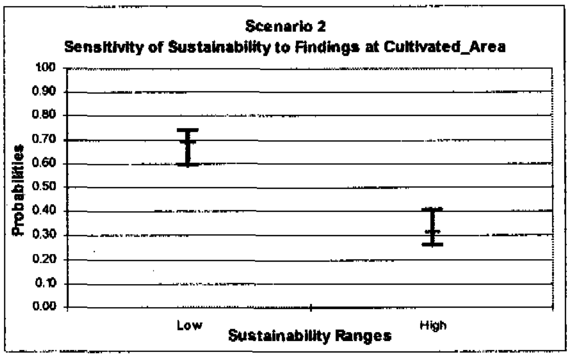


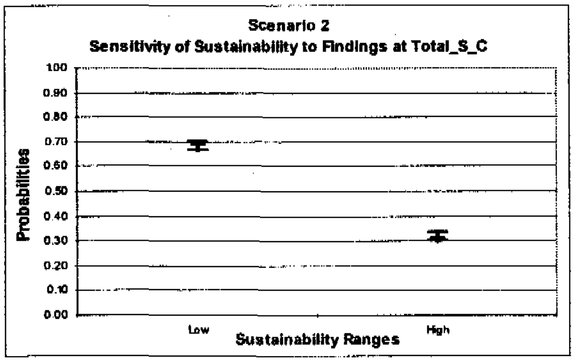

Scenario 2
Sensitivity of Sustainability to Findings at Yield_improve
Probabilities
100
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Low
High
Sustainability Ranges

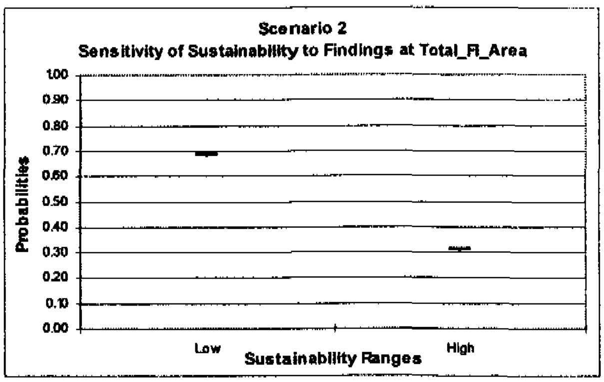

Scenario 2
Sensitivity of Sustainability to Findings at Rainfall
Probabilities
100
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Low
High
Sustainability Ranges

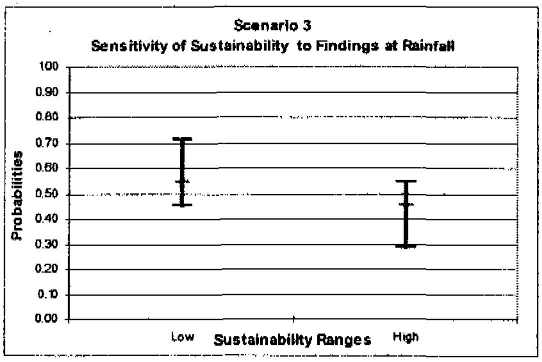

Scenario 2
Sensitivity of Sustainability to Findings at Labor Contribution
Probabilities
100
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Low
High
Sustainability Ranges

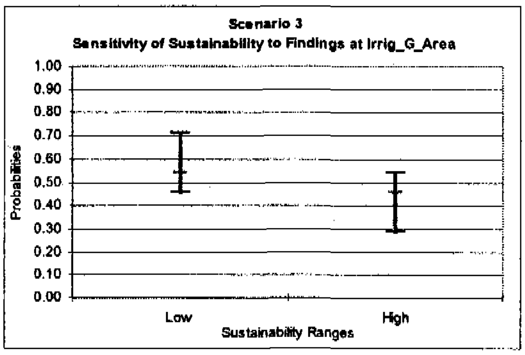

Scenario 2
Sensitivity of Sustainability to Findings at Rainfall
Probabilities
100
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Low
High
Sustainability Ranges

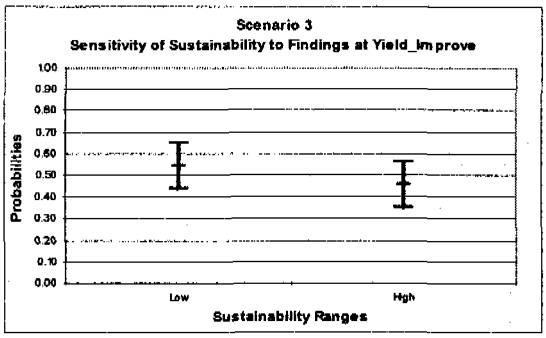

Scenario 2
Sensitivity of Sustainability to Findings at Cultivated_Area
Probabilities
100
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Low
High
Sustainability Ranges

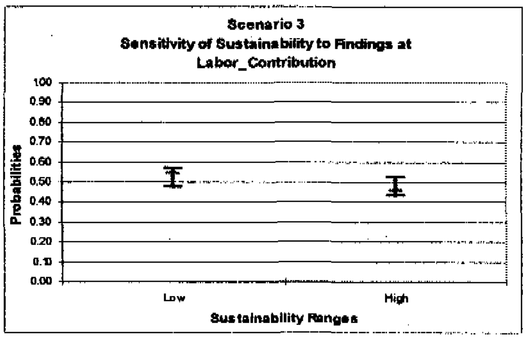

Scenario 2
Sensitivity of Sustainability to Findings at Total_S_C
Probabilities
100
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Low
High
Sustainability Ranges

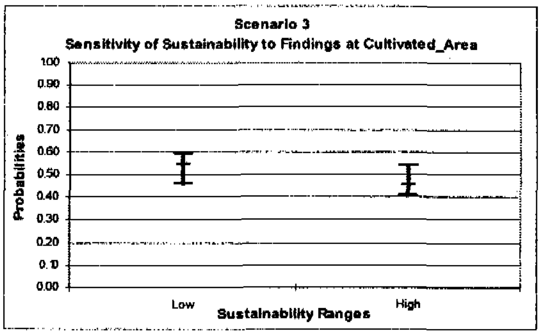

Scenario 2
Sensitivity of Sustainability to Findings at Total_Fl_Area
Probabilities
100
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Low
High
Sustainability Ranges

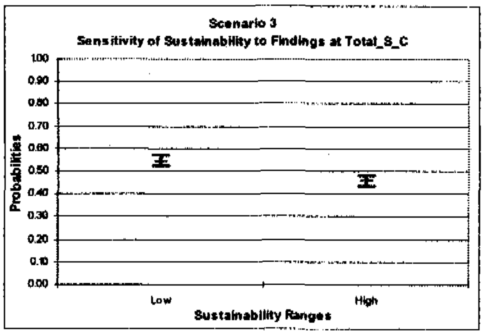

Scenario 3
Sensitivity of Sustainability to Findings at Rainfall
Probabilities
Low
Sustainability Ranges
High

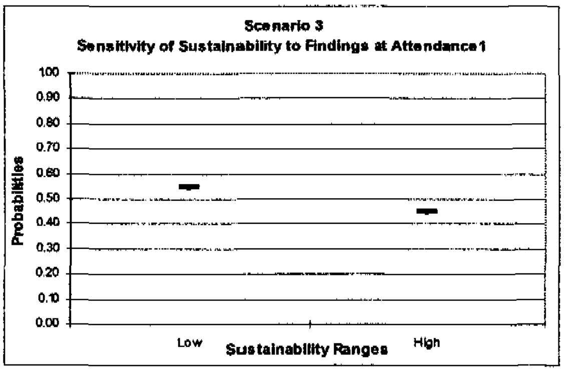

Scenario 3
Sensitivity of Sustainability to Findings at Irrig_G_Area
Probabilities
Low
High
Sustainability Ranges

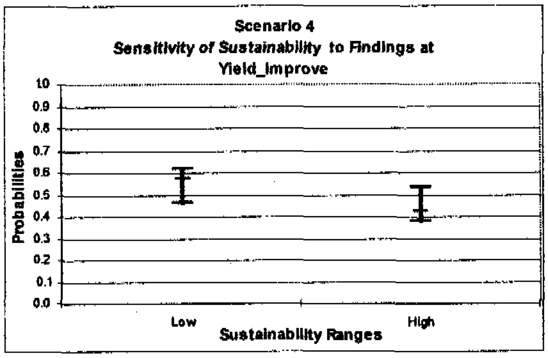

Scenario 3
Sensitivity of Sustainability to Findings at Yield_Improve
Probabilities
Low
High
Sustainability Ranges

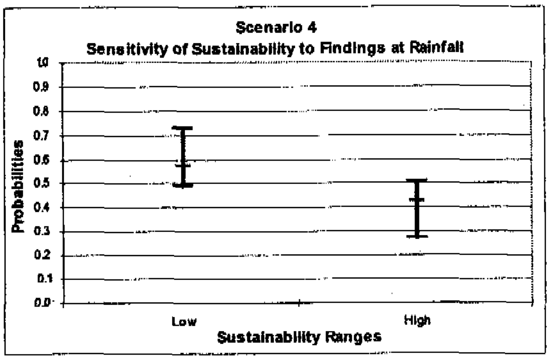

Scenario 3
Sensitivity of Sustainability to Findings at Labor_Contribution
Probabilities
Low
High
Sustainability Ranges

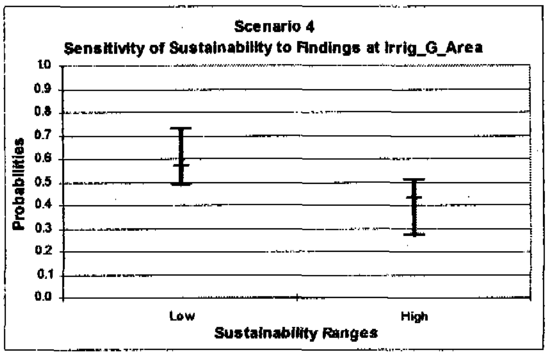

Scenario 3
Sensitivity of Sustainability to Findings at Cultivated_Area
Probabilities
Low
Sustainability Ranges
High

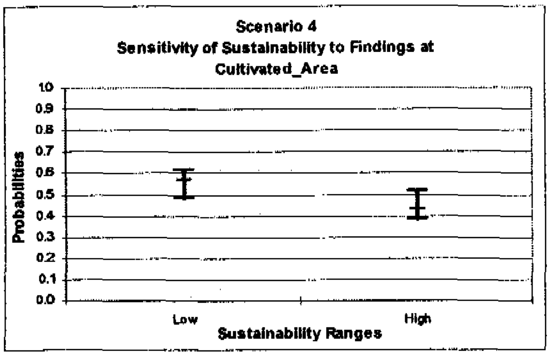

Scenario 3
Sensitivity of Sustainability to Findings at Total_S_C
Probabilities
Low
High
Sustainability Ranges

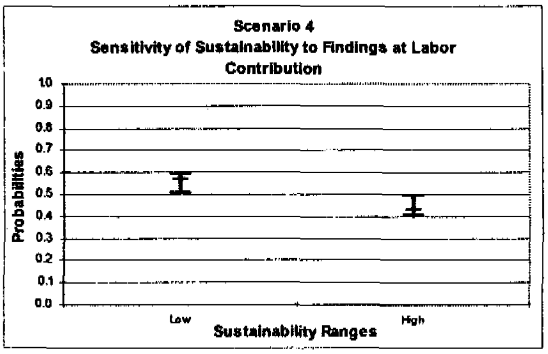

Scenario 3
Sensitivity of Sustainability to Findings at Attendance1
Probabilities
Low
Sustainability Ranges
High

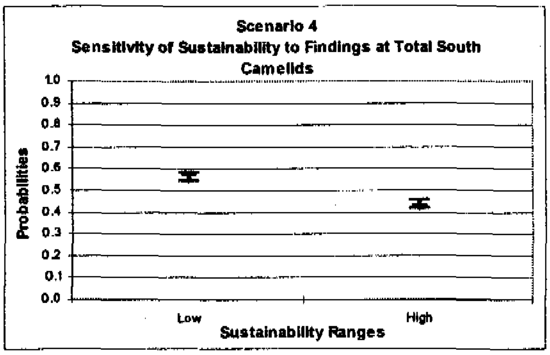

Scenario 4
Sensitivity of Sustainability to Findings at Yield_Improve
Probabilities
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Low
High
Sustainability Ranges


Scenario 4
Sensitivity of Sustainability to Findings at Rainfall
Probabilities
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Low
High
Sustainability Ranges

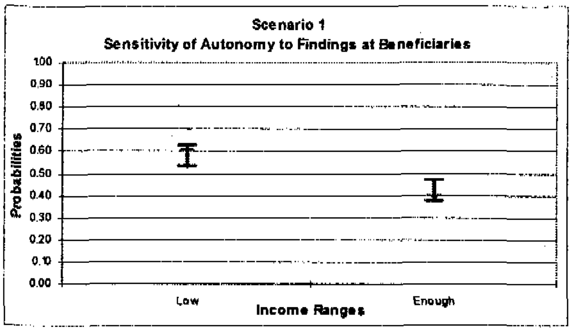

Scenario 4
Sensitivity of Sustainability to Findings at Irrig_G_Area
Probabilities
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Low
High
Sustainability Ranges

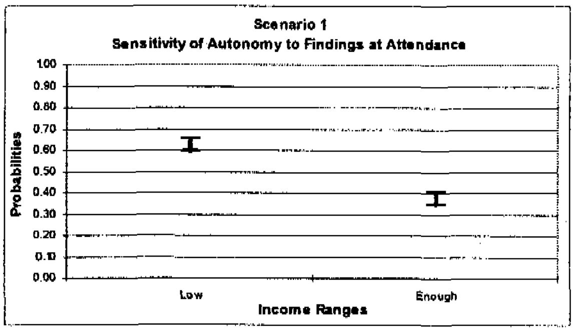

Scenario 4
Sensitivity of Sustainability to Findings at Cultivated_Area
Probabilities
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Low
High
Sustainability Ranges

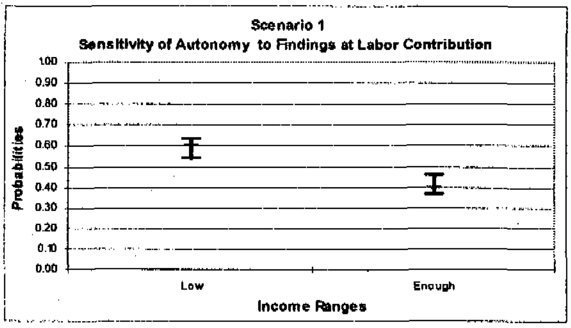

Scenario 4
Sensitivity of Sustainability to Findings at Labor Contribution
Probabilities
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Low
High
Sustainability Ranges

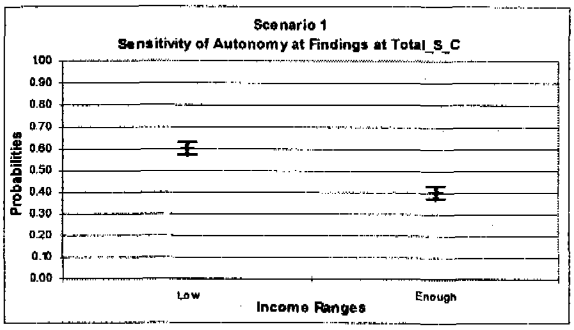

Scenario 4
Sensitivity of Sustainability to Findings at Total South Camelids
Probabilities
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Low
High
Sustainability Ranges

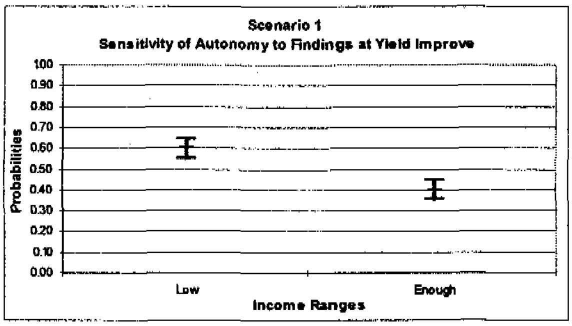
2.3 Autonomy

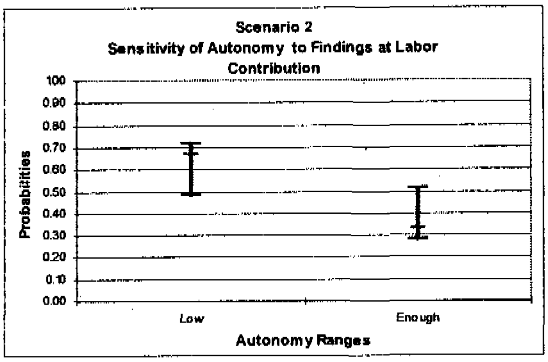

Scenario 1
Sensitivity of Autonomy to Findings at Beneficiaries
Probabilities
Low
Enough
Income Ranges

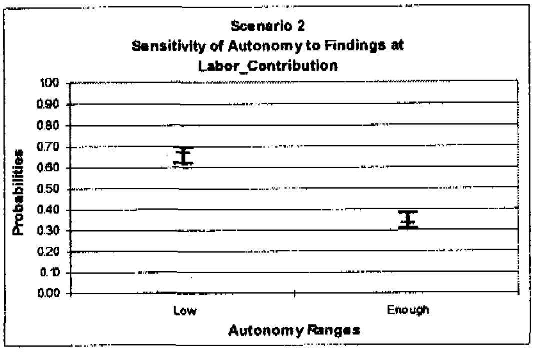

Scenario 1
Sensitivity of Autonomy to Findings at Attendance
Probabilities
Low
Enough
Income Ranges

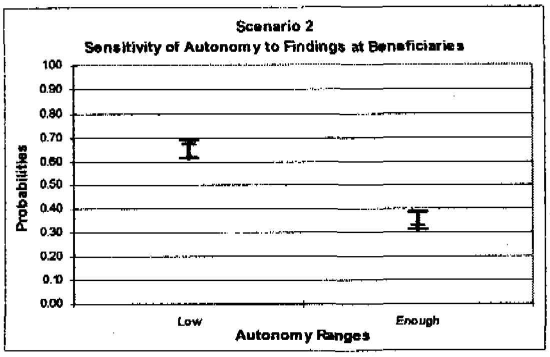

Scenario 1
Sensitivity of Autonomy to Findings at Labor Contribution
Probabilities
Low
Enough
Income Ranges

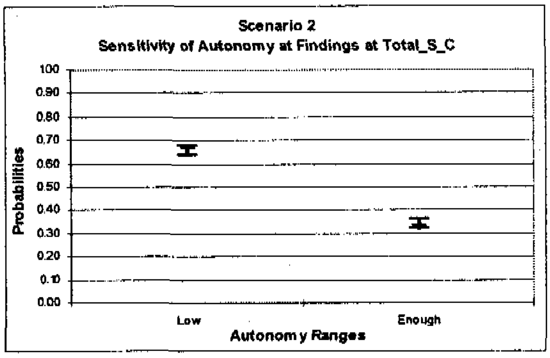

Scenario 1
Sensitivity of Autonomy at Findings at Total_S_C
Probabilities
Low
Enough
Income Ranges

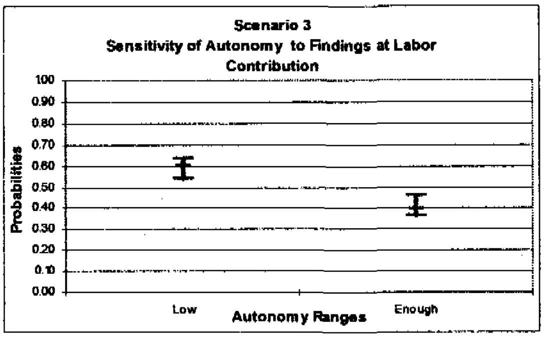

Scenario 1
Sensitivity of Autonomy to Findings at Yield Improve
Probabilities
Low
Enough
Income Ranges

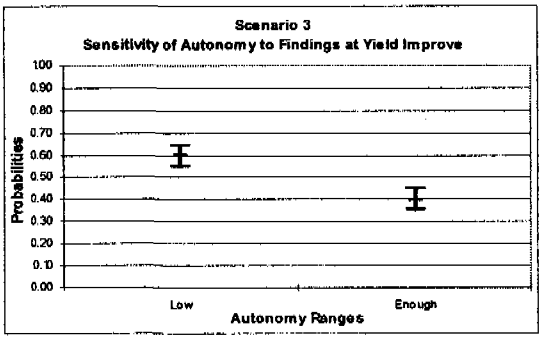

Scenario 2
Sensitivity of Autonomy to Findings at Labor Contribution
Probabilities
Low
Enough
Autonomy Ranges

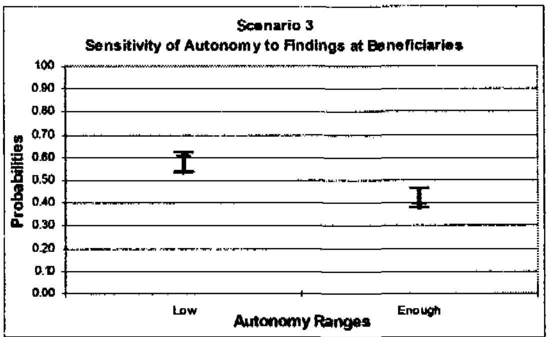

Scenario 2
Sensitivity of Autonomy to Findings at Labor_Contribution
Probabilities
Low
Enough
Autonomy Ranges

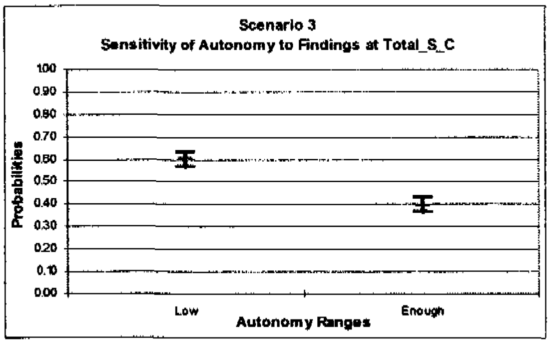

Scenario 2
Sensitivity of Autonomy to Findings at Beneficiaries
Probabilities
Low
Enough
Autonomy Ranges

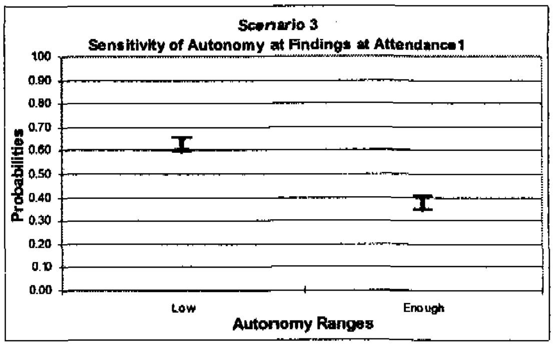

Scenario 2
Sensitivity of Autonomy at Findings at Total_S_C
Probabilities
Low
Enough
Autonomy Ranges

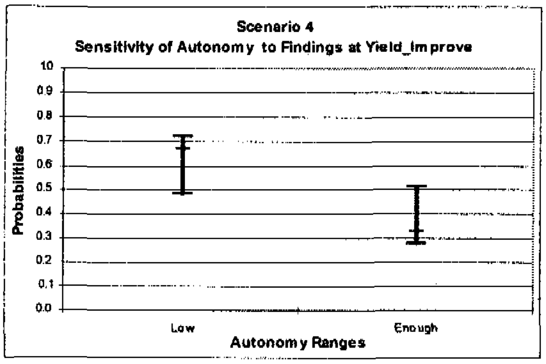

Scenario 3
Sensitivity of Autonomy to Findings at Labor Contribution
Probabilities
Low
Autonomy Ranges
Enough

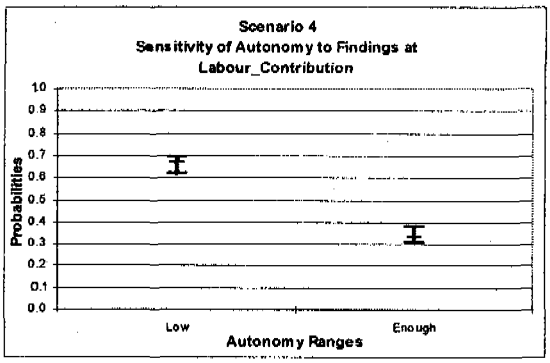

Scenario 3
Sensitivity of Autonomy to Findings at Yield Improve
Probabilities
Low
Enough
Autonomy Ranges

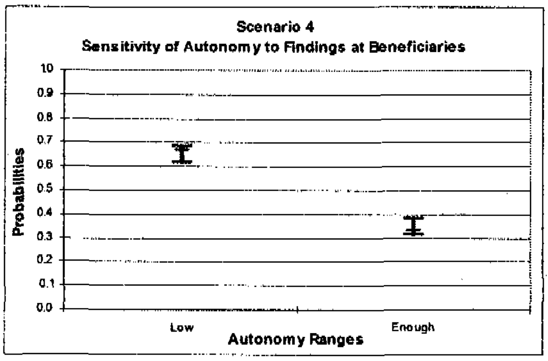

Scenario 3
Sensitivity of Autonomy to Findings at Beneficiaries
Probabilities
Low
Enough
Autonomy Ranges

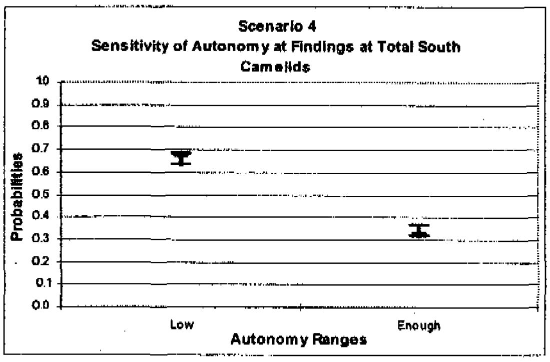

Scenario 3
Sensitivity of Autonomy to Findings at Total_S_C
Probabilities
Low
Enough
Autonomy Ranges


Scenario 3
Sensitivity of Autonomy at Findings at Attendance1
Probabilities
Low
Enough
Autonomy Ranges

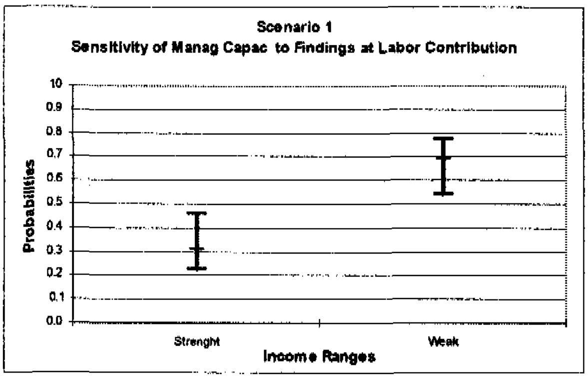


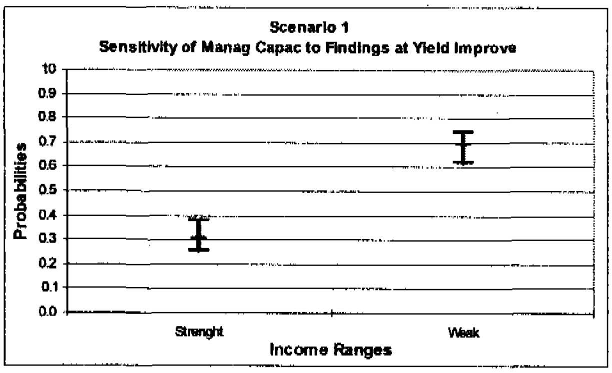


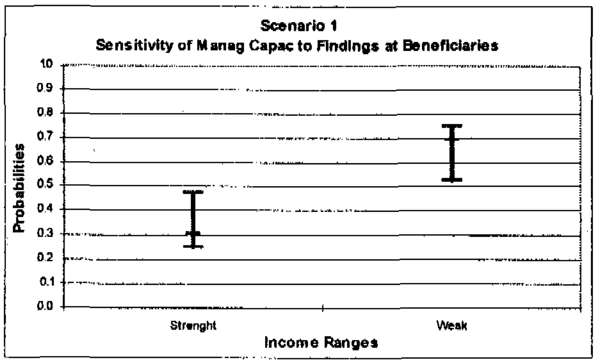


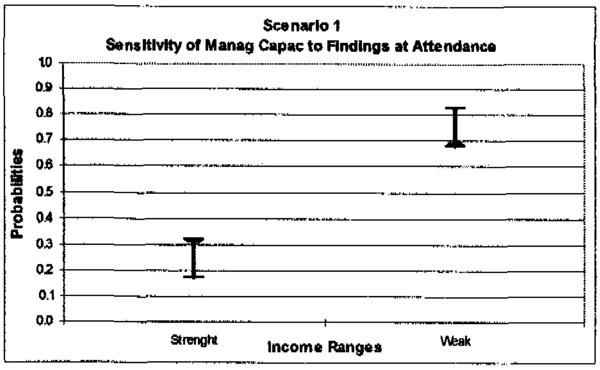


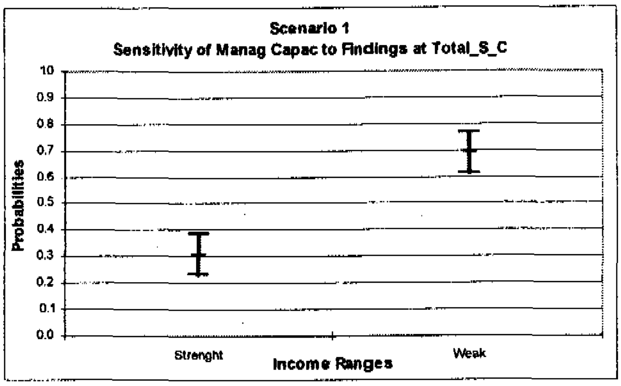
2.4 Management Capacity

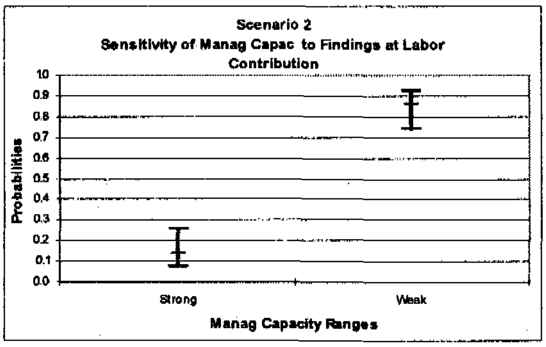


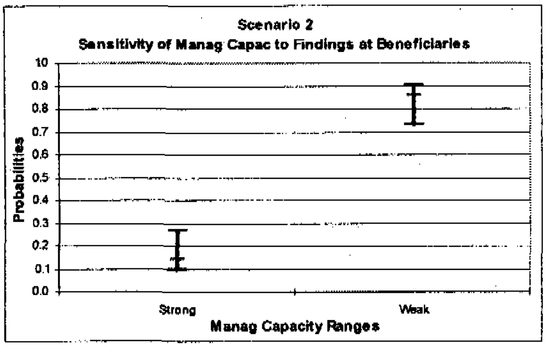


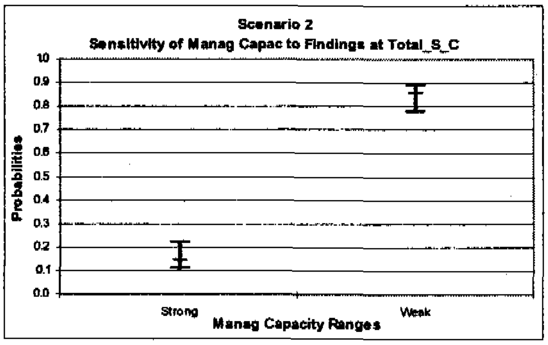


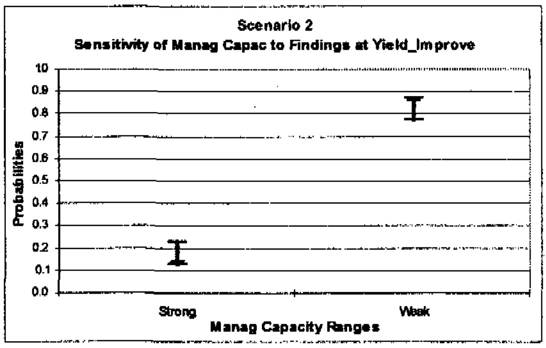


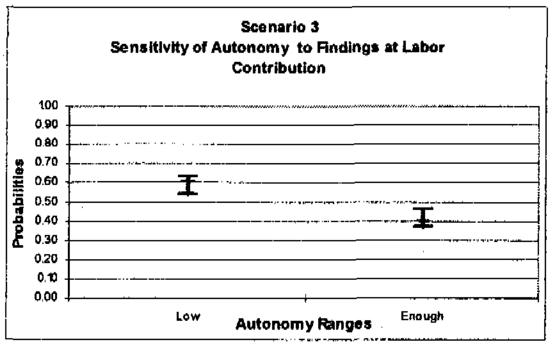

Scenario 1
Sensitivity of Manag Capac to Findings at Total_S_C
Probabilities
Strenght
Weak
Income Ranges

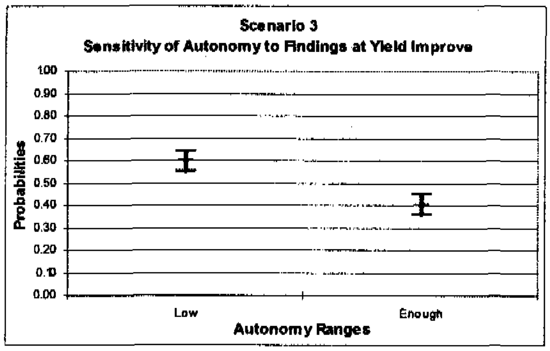

Scenario 2
Sensitivity of Manag Capac to Findings at Labor Contribution
Probabilities
Strong
Weak
Manag Capacity Ranges

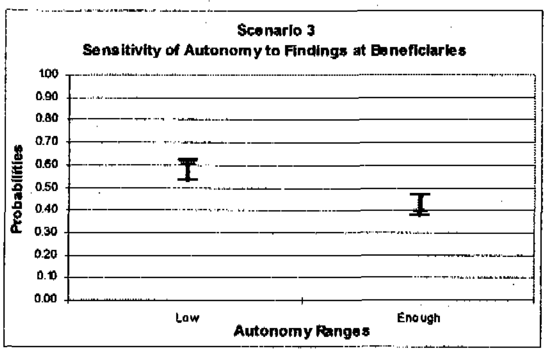

Scenario 2
Sensitivity of Manag Capac to Findings at Beneficiaries
Probabilities
Strong
Weak
Manag Capacity Ranges

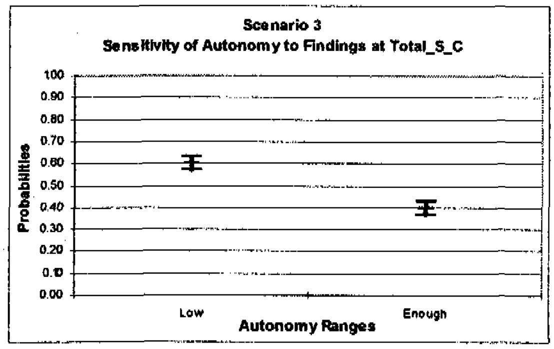

Scenario 2
Sensitivity of Manag Capac to Findings at Total_S_C
Probabilities
Strong
Weak
Manag Capacity Ranges

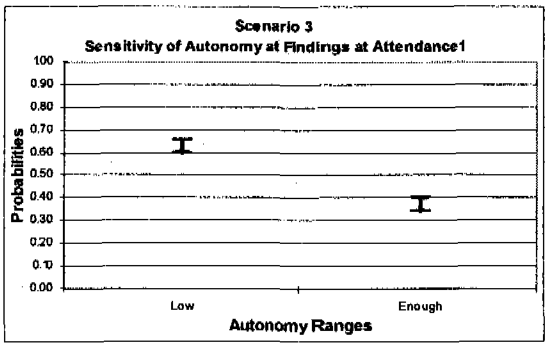

Scenario 2
Sensitivity of Manag Capac to Findings at Yield_Improve
Probabilities
Strong
Weak
Manag Capacity Ranges

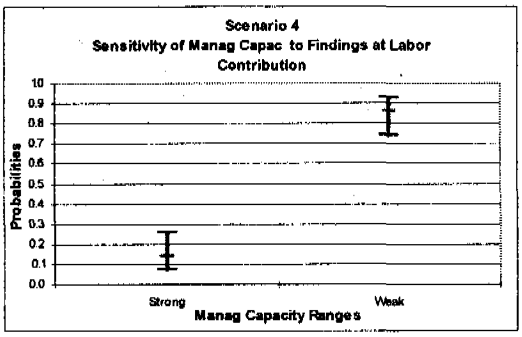

Scenario 3
Sensitivity of Autonomy to Findings at Labor Contribution
Probabilities
100
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Low
Enough
Autonomy Ranges

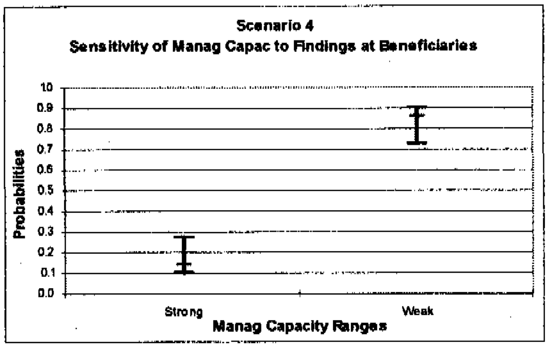

Scenario 3
Sensitivity of Autonomy to Findings at Yield Improve
Probabilities
100
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Low
Enough
Autonomy Ranges

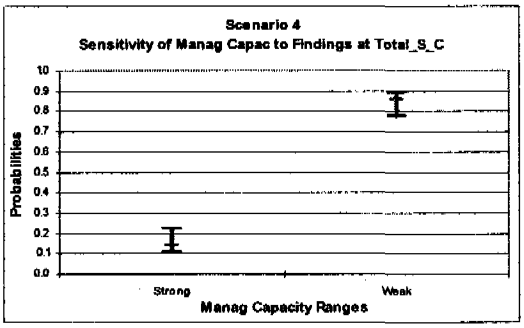

Scenario 3
Sensitivity of Autonomy to Findings at Beneficiaries
Probabilities
100
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Low
Enough
Autonomy Ranges

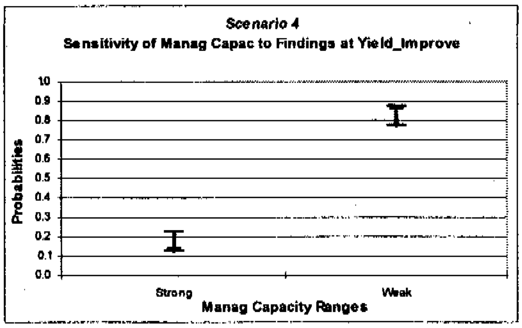

Scenario 3
Sensitivity of Autonomy to Findings at Total_S_C
Probabilities
100
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Low
Enough
Autonomy Ranges


Scenario 3
Sensitivity of Autonomy at Findings at Attendance1
Probabilities
100
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Low
Enough
Autonomy Ranges

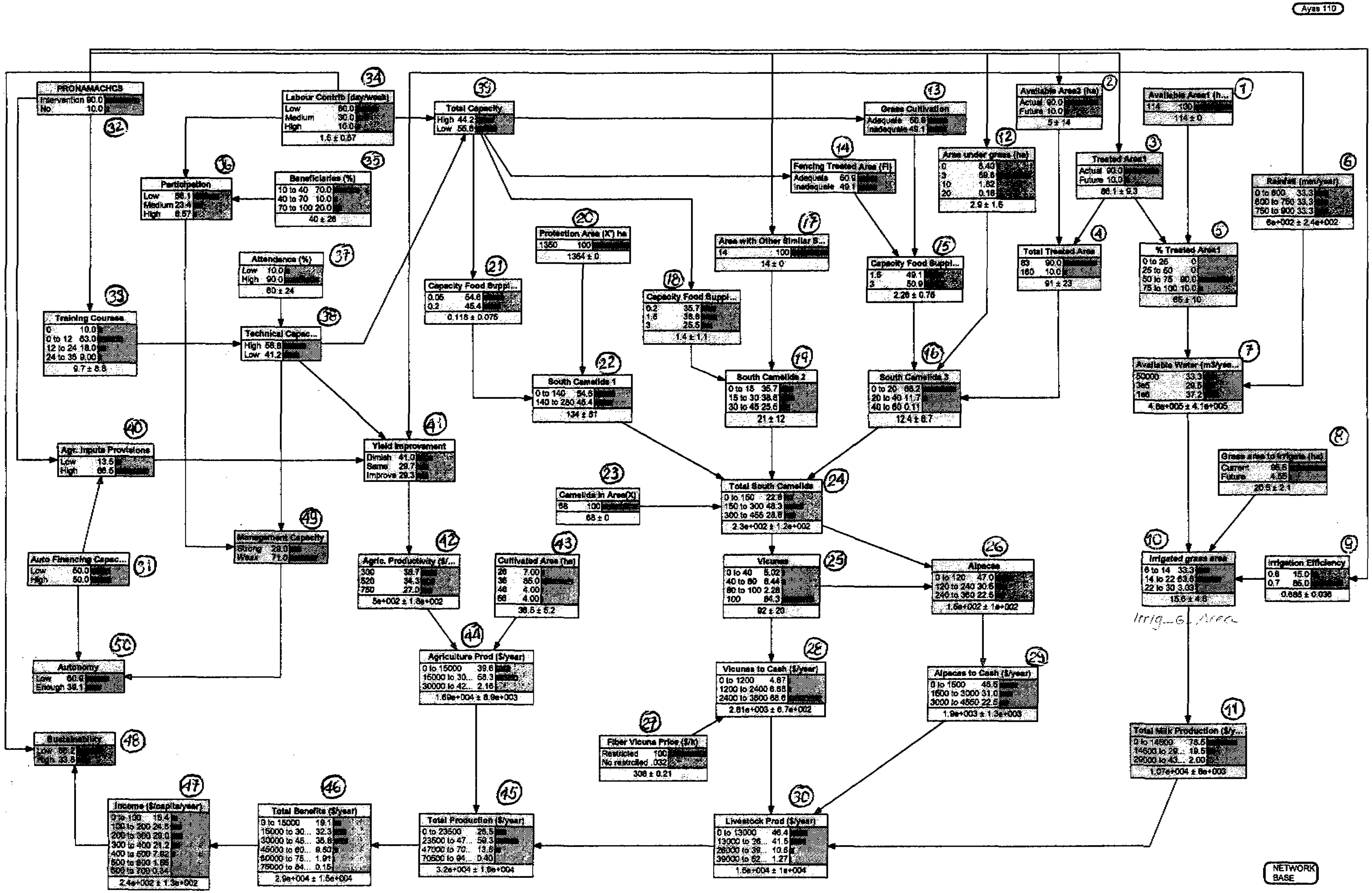

Scenario 4
Sensitivity of Manag Capac to Findings at Labor Contribution
Probabilities
Strong
Weak
Manag Capacity Ranges


Scenario 4
Sensitivity of Manag Capac to Findings at Beneficiaries
Probabilities
Strong
Weak
Manag Capacity Ranges

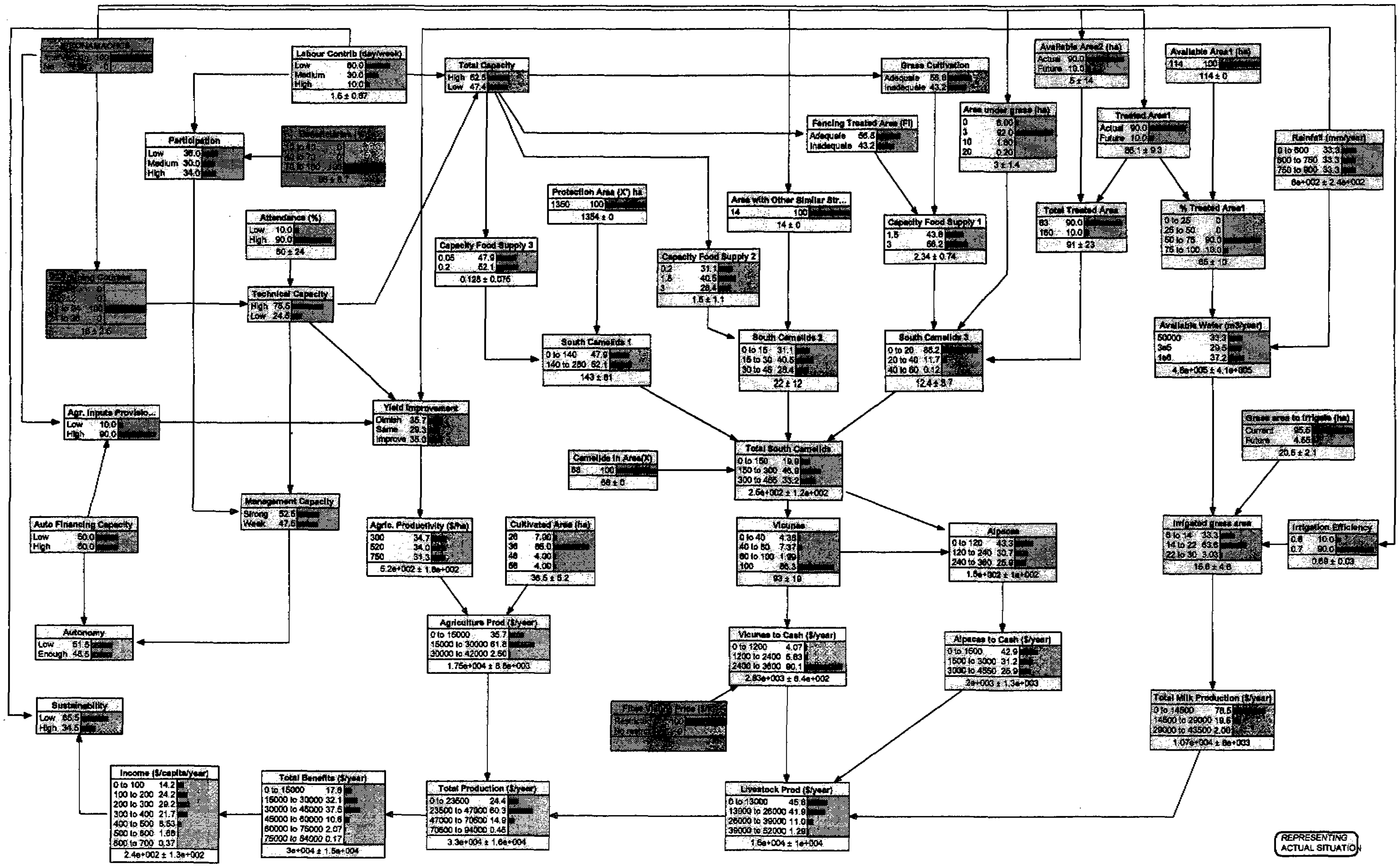

Scenario 4
Sensitivity of Manag Capac to Findings at Total_S_C
Probabilities
Strong
Weak
Manag Capacity Ranges


Scenario 4
Sensitivity of Manag Capac to Findings at Yield_Improve
Probabilities
Strong
Weak
Manag Capacity Ranges

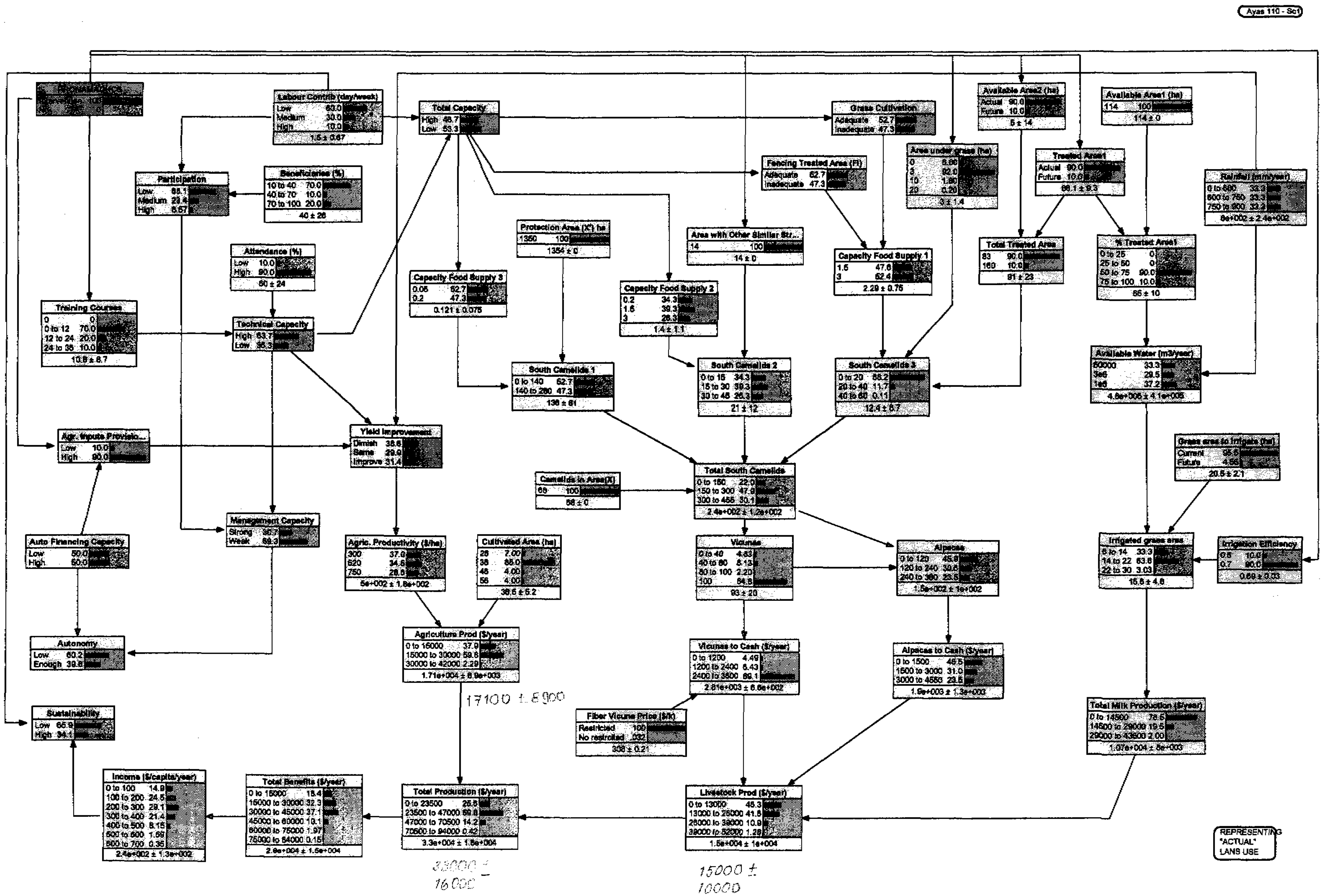
Annex IV: Bayesian Network Graphs

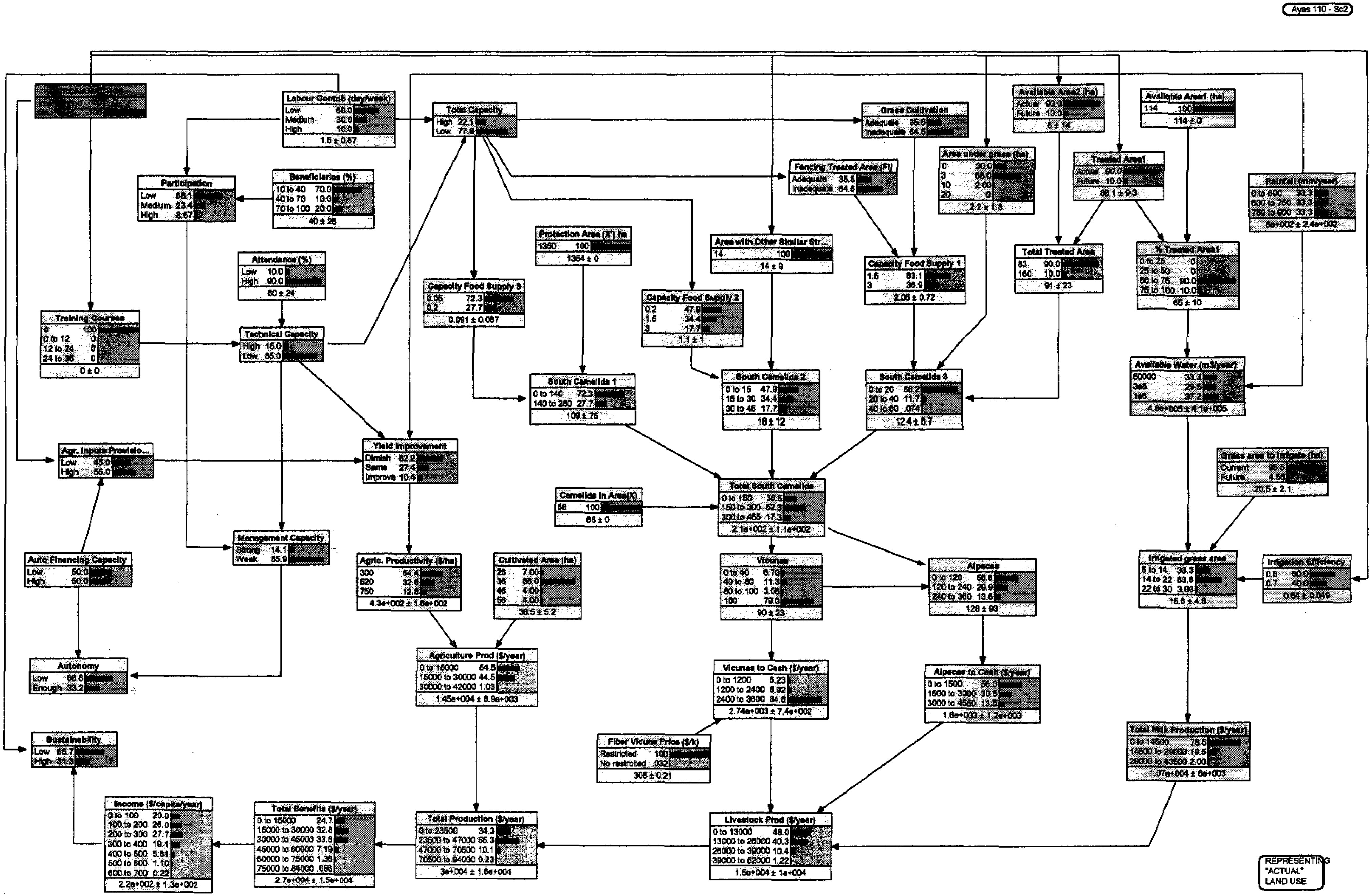

Ayas 110
PRONAMACHCS
Intervention 90.0
No 10.0
Labour Contrib (day/week)
Low 60.0
Medium 30.0
High 10.0
1.6 ± 0.87
Total Capacity
High 44.2
Low 55.8
Grass Cultivation
Adequate 50.9
Inadequate 49.1
Available Area2 (ha)
Actual 90.0
Future 10.0
5 ± 14
Available Area1 (h...
114 100
114 ± 0
Participation
Low 66.1
Medium 23.4
High 6.57
Beneficiaries (%)
10 to 40 70.0
40 to 70 10.0
70 to 100 20.0
40 ± 26
Fencing Treated Area (FI)
Adequate 50.9
Inadequate 49.1
Area under grass (ha)
0 8.40
3 89.6
10 1.82
20 0.18
2.9 ± 1.5
Treated Area1
Actual 90.0
Future 10.0
86.1 ± 9.3
Rainfall (mm/year)
0 to 600 33.3
600 to 750 33.3
750 to 900 33.3
6e+002 ± 2.4e+002
Protection Area (X') ha
1350 100
1354 ± 0
Area with Other Similar S...
14 100
14 ± 0
Attendance (%)
Low 10.0
High 90.0
80 ± 24
Capacity Food Suppl...
0.05 54.6
0.2 45.4
0.118 ± 0.075
Capacity Food Suppl...
0.2 35.7
1.6 38.8
3 25.5
1.4 ± 1.1
Capacity Food Suppl...
1.6 49.1
3 50.9
2.28 ± 0.76
Total Treated Area
83 90.0
160 10.0
91 ± 23
% Treated Area1
0 to 25 0
25 to 50 0
50 to 75 90.0
75 to 100 10.0
65 ± 10
Training Courses
0 10.0
0 to 12 63.0
12 to 24 18.0
24 to 36 9.00
9.7 ± 8.8
Technical Capac...
High 58.8
Low 41.2
South Camelids 1
0 to 140 54.6
140 to 280 45.4
134 ± 61
South Camelids 2
0 to 15 35.7
15 to 30 38.8
30 to 45 25.5
21 ± 12
South Camelids 3
0 to 20 88.2
20 to 40 11.7
40 to 60 0.11
12.4 ± 6.7
Available Water (m3/yea...
50000 33.3
3e5 29.5
1e6 37.2
4.8e+005 ± 4.1e+005
Agr. Inputs Provisions
Low 13.5
High 86.5
Yield Improvement
Diminish 41.0
Same 29.7
Improve 29.3
Grass area to irrigate (ha)
Current 95.5
Future 4.55
20.5 ± 2.1
Camelids in Area(X)
68 100
68 ± 0
Total South Camelids
0 to 150 22.9
150 to 300 48.3
300 to 455 28.8
2.3e+002 ± 1.2e+002
Management Capacity
Strong 29.0
Weak 71.0
Auto Financing Capac...
Low 50.0
High 50.0
Agric. Productivity ($/...
300 38.7
520 34.3
750 27.0
5e+002 ± 1.8e+002
Cultivated Area (ha)
20 7.00
36 85.0
46 4.00
66 4.00
36.5 ± 5.2
Vicunas
0 to 40 5.02
40 to 80 8.44
80 to 100 2.26
100 84.3
92 ± 20
Alpacas
0 to 120 47.0
120 to 240 30.6
240 to 360 22.5
1.5e+002 ± 1e+002
Irrigated grass area
6 to 14 33.3
14 to 22 63.6
22 to 30 3.03
15.6 ± 4.8
Irrigation Efficiency
0.6 15.0
0.7 85.0
0.685 ± 0.036
Irrig_G_Area
Autonomy
Low 60.9
Enough 39.1
Agriculture Prod ($/year)
0 to 15000 39.6
15000 to 30... 58.3
30000 to 42... 2.16
1.69e+004 ± 8.9e+003
Vicunas to Cash ($/year)
0 to 1200 4.67
1200 to 2400 6.65
2400 to 3600 88.6
2.81e+003 ± 6.7e+002
Alpacas to Cash ($/year)
0 to 1500 46.5
1500 to 3000 31.0
3000 to 4550 22.5
1.9e+003 ± 1.3e+003
Sustainability
Low 66.2
High 33.8
Fiber Vicuna Price ($/k)
Restricted 100
No restricted .032
308 ± 0.21
Total Milk Production ($/y...
0 to 14600 78.5
14600 to 29... 19.5
29000 to 43... 2.00
1.07e+004 ± 8e+003
Income ($/capita/year)
0 to 100 15.4
100 to 200 24.8
200 to 300 29.0
300 to 400 21.2
400 to 500 7.62
500 to 600 1.65
600 to 700 0.34
2.4e+002 ± 1.3e+002
Total Benefits ($/year)
0 to 15000 19.1
15000 to 30... 32.3
30000 to 45... 35.8
45000 to 60... 9.60
60000 to 75... 1.91
75000 to 84... 0.15
2.9e+004 ± 1.5e+004
Total Production ($/year)
0 to 23500 26.5
23500 to 47... 59.3
47000 to 70... 13.8
70500 to 94... 0.40
3.2e+004 ± 1.8e+004
Livestock Prod ($/year)
0 to 13000 46.4
13000 to 26... 41.5
26000 to 39... 10.8
39000 to 52... 1.27
1.5e+004 ± 1e+004
NETWORK BASE

Ayes 110 - 00



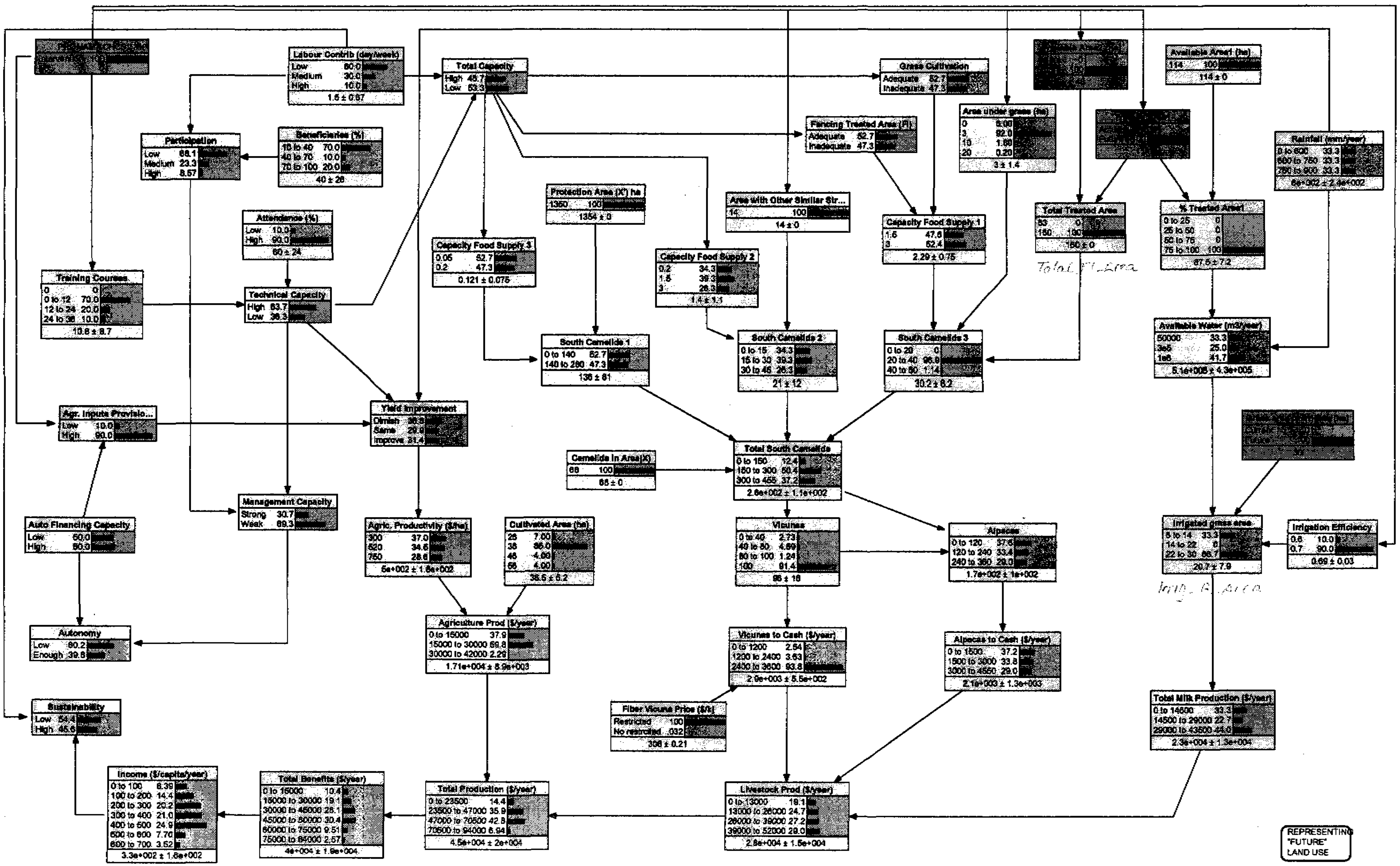
REPRESENTING ACTUAL SITUATION


Ayas 110 - Sc1
Labour Contrib (day/week)
Low 60.0
Medium 30.0
High 10.0
1.5 ± 0.67
Total Capacity
High 46.7
Low 53.3
Grass Cultivation
Adequate 52.7
Inadequate 47.3
Available Area2 (ha)
Actual 90.0
Future 10.0
5 ± 14
Available Area1 (ha)
114 100
114 ± 0
Participation
Low 68.1
Medium 23.4
High 8.57
Beneficiaries (%)
10 to 40 70.0
40 to 70 10.0
70 to 100 20.0
40 ± 26
Fencing Treated Area (FI)
Adequate 52.7
Inadequate 47.3
Area under grass (ha)
0 6.00
5 92.0
10 1.80
20 0.20
3 ± 1.4
Treated Area1
Actual 90.0
Future 10.0
96.1 ± 9.3
Rainfall (mm/year)
0 to 600 33.3
600 to 750 33.3
750 to 900 33.3
6e+002 ± 2.4e+002
Attendance (%)
Low 10.0
High 90.0
80 ± 24
Protection Area (X') ha
1350 100
1354 ± 0
Area with Other Similar Str...
14 100
14 ± 0
Capacity Food Supply 1
1.5 47.6
3 52.4
2.29 ± 0.75
Total Treated Area
83 90.0
160 10.0
91 ± 23
% Treated Area1
0 to 25 0
25 to 50 0
50 to 75 90.0
75 to 100 10.0
65 ± 10
Capacity Food Supply 3
0.05 52.7
0.2 47.3
0.121 ± 0.075
Capacity Food Supply 2
0.2 34.3
1.5 39.3
3 26.3
1.4 ± 1.1
Training Courses
0 0
0 to 12 70.0
12 to 24 20.0
24 to 36 10.0
10.9 ± 8.7
Technical Capacity
High 63.7
Low 36.3
South Camelids 1
0 to 140 52.7
140 to 280 47.3
136 ± 81
South Camelids 2
0 to 15 34.3
15 to 30 39.3
30 to 45 26.3
21 ± 12
South Camelids 3
0 to 20 88.2
20 to 40 11.7
40 to 60 0.11
12.4 ± 6.7
Available Water (m3/year)
50000 33.3
3e6 29.5
1e6 37.2
4.6e+006 ± 4.1e+005
Agr. Inputs Provisio...
Low 10.0
High 90.0
Yield Improvement
Dimish 38.6
Same 29.9
Improve 31.4
Total South Camelids
0 to 150 22.0
150 to 300 47.9
300 to 455 30.1
2.4e+002 ± 1.2e+002
Camelids in Area(X)
66 100
66 ± 0
Grass area to irrigate (ha)
Current 95.5
Future 4.50
20.5 ± 2.1
Auto Financing Capacity
Low 50.0
High 50.0
Management Capacity
Strong 30.7
Weak 69.3
Agric. Productivity ($/ha)
300 37.0
520 34.6
750 28.5
5e+002 ± 1.8e+002
Cultivated Area (ha)
28 7.00
35 85.0
45 4.00
56 4.00
36.5 ± 5.2
Vicunas
0 to 40 4.83
40 to 80 8.13
80 to 100 2.20
100 84.8
93 ± 20
Alpacas
0 to 120 45.6
120 to 240 30.8
240 to 360 23.5
1.5e+002 ± 1e+002
Irrigated grass area
6 to 14 33.3
14 to 22 63.6
22 to 30 3.03
15.6 ± 4.8
Irrigation Efficiency
0.5 10.0
0.7 90.0
0.69 ± 0.03
Autonomy
Low 60.2
Enough 39.8
Agriculture Prod ($/year)
0 to 15000 37.9
15000 to 30000 59.8
30000 to 42000 2.29
1.71e+004 ± 6.9e+003
Vicunas to Cash ($/year)
0 to 1200 4.49
1200 to 2400 6.43
2400 to 3600 89.1
2.81e+003 ± 6.6e+002
Alpacas to Cash ($/year)
0 to 1500 45.5
1500 to 3000 31.0
3000 to 4550 23.5
1.9e+003 ± 1.3e+003
17100 ± 6900
Fiber Vicuna Price ($/k)
Restricted 100
No restricted .032
308 ± 0.21
Total Milk Production ($/year)
0 to 14500 78.5
14500 to 29000 19.5
29000 to 43500 2.00
1.07e+004 ± 8e+003
Sustainability
Low 65.9
High 34.1
Income ($/capita/year)
0 to 100 14.9
100 to 200 24.5
200 to 300 29.1
300 to 400 21.4
400 to 500 8.15
500 to 600 1.69
600 to 700 0.35
2.4e+002 ± 1.3e+002
Total Benefits ($/year)
0 to 15000 15.4
15000 to 30000 32.3
30000 to 45000 37.1
45000 to 60000 10.1
60000 to 75000 1.97
75000 to 84000 0.15
2.9e+004 ± 1.5e+004
Total Production ($/year)
0 to 23500 25.8
23500 to 47000 59.6
47000 to 70500 14.2
70500 to 94000 0.42
3.3e+004 ± 1.8e+004
Livestock Prod ($/year)
0 to 13000 45.3
13000 to 26000 41.5
26000 to 39000 10.9
39000 to 52000 1.29
1.5e+004 ± 1e+004
REPRESENTING "ACTUAL" LANS USE
33000 ± 16000
15000 ± 10000

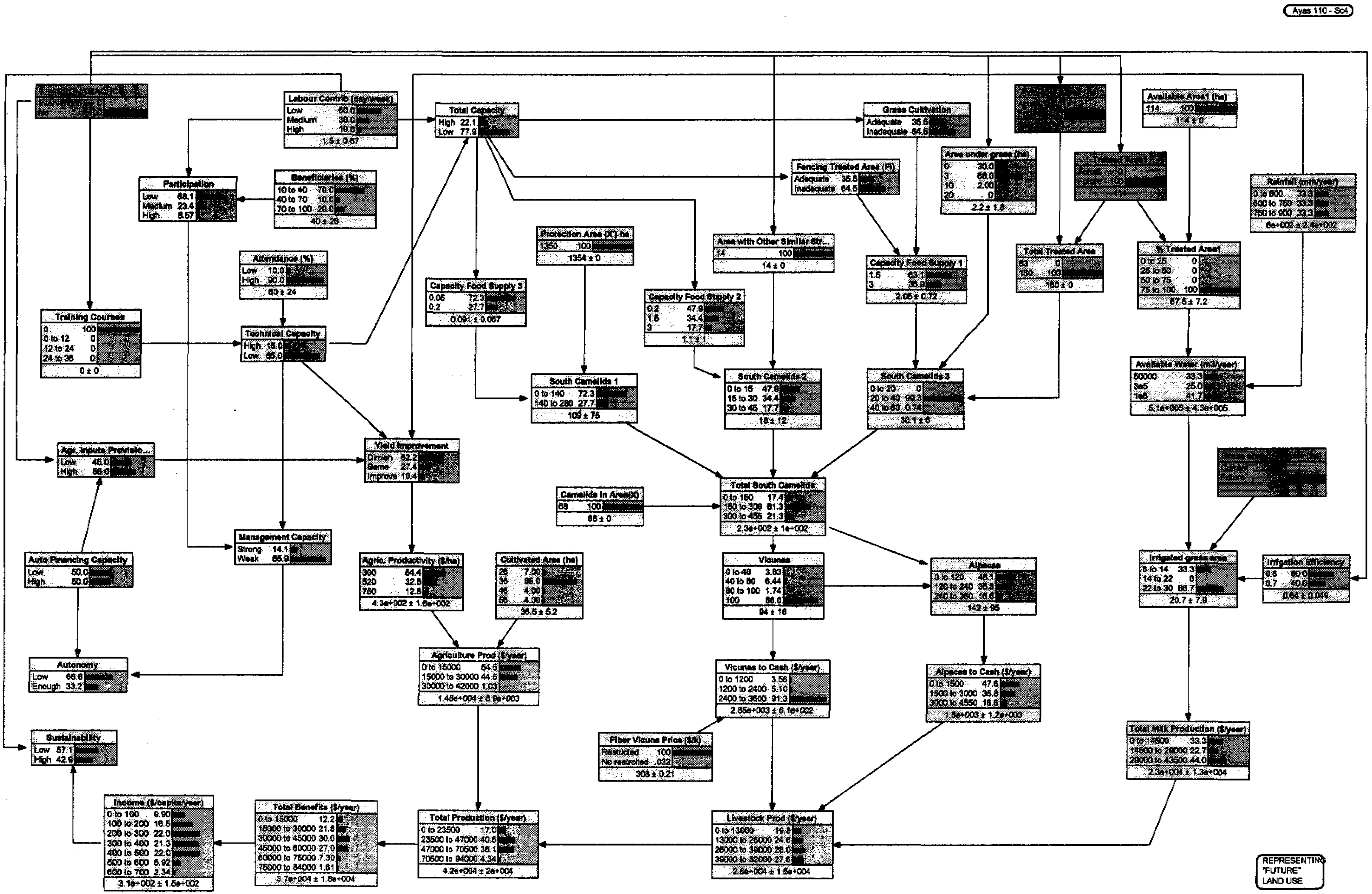


Ayas 110 - Sc2
Labour Contrib (day/week)
Low 60.0
Medium 30.0
High 10.0
1.5 ± 0.87
Total Capacity
High 22.1
Low 77.9
Grass Cultivation
Adequate 35.5
Inadequate 64.5
Available Area2 (ha)
Actual 90.0
Future 10.0
5 ± 14
Available Area1 (ha)
114 100
114 ± 0
Participation
Low 68.1
Medium 23.4
High 8.57
Beneficiaries (%)
10 to 40 70.0
40 to 70 10.0
70 to 100 20.0
40 ± 26
Fencing Treated Area (FI)
Adequate 35.5
Inadequate 64.5
Area under grass (ha)
0 30.0
3 68.0
10 2.00
20 0
2.2 ± 1.8
Treated Area1
Actual 90.0
Future 10.0
86.1 ± 9.3
Rainfall (mm/year)
0 to 600 33.3
600 to 750 33.3
750 to 900 33.3
6e+002 ± 2.4e+002
Protection Area (X) ha
1350 100
1354 ± 0
Area with Other Similar Str...
14 100
14 ± 0
Attendance (%)
Low 10.0
High 90.0
80 ± 24
Capacity Food Supply 3
0.05 72.3
0.2 27.7
0.091 ± 0.067
Capacity Food Supply 2
0.2 47.9
1.5 34.4
3 17.7
1.1 ± 1
Capacity Food Supply 1
1.5 63.1
3 36.9
2.05 ± 0.72
Total Treated Area
83 90.0
150 10.0
91 ± 23
% Treated Area1
0 to 25 0
25 to 50 0
50 to 75 90.0
75 to 100 10.0
65 ± 10
Training Courses
0 100
0 to 12 0
12 to 24 0
24 to 36 0
0 ± 0
Technical Capacity
High 15.0
Low 85.0
South Camelids 1
0 to 140 72.3
140 to 280 27.7
109 ± 75
South Camelids 2
0 to 15 47.9
15 to 30 34.4
30 to 45 17.7
18 ± 12
South Camelids 3
0 to 20 88.2
20 to 40 11.7
40 to 60 .074
12.4 ± 6.7
Available Water (m3/year)
50000 33.3
3e5 29.5
1e6 37.2
4.8e+005 ± 4.1e+005
Agr. Inputs Provisio...
Low 45.0
High 55.0
Yield Improvement
Dimish 62.2
Same 27.4
Improve 10.4
Grass area to irrigate (ha)
Current 95.5
Future 4.50
20.5 ± 2.1
Camelids in Area(X)
56 100
56 ± 0
Total South Camelids
0 to 150 30.5
150 to 300 52.3
300 to 455 17.3
2.1e+002 ± 1.1e+002
Management Capacity
Strong 14.1
Weak 85.9
Auto Financing Capacity
Low 50.0
High 50.0
Agric. Productivity ($/ha)
300 54.4
520 32.8
750 12.8
4.3e+002 ± 1.8e+002
Cultivated Area (ha)
25 7.00
36 85.0
46 4.00
56 4.00
36.5 ± 5.2
Vicunas
0 to 40 6.70
40 to 80 11.3
80 to 100 3.06
100 79.0
90 ± 23
Alpacas
0 to 120 56.6
120 to 240 29.9
240 to 360 13.5
128 ± 93
Irrigated grass area
8 to 14 33.3
14 to 22 63.6
22 to 30 3.03
15.8 ± 4.8
Irrigation Efficiency
0.6 60.0
0.7 40.0
0.64 ± 0.049
Autonomy
Low 66.8
Enough 33.2
Agriculture Prod ($/year)
0 to 15000 54.5
15000 to 30000 44.5
30000 to 42000 1.03
1.45e+004 ± 8.9e+003
Vicunas to Cash ($/year)
0 to 1200 8.23
1200 to 2400 6.92
2400 to 3600 84.8
2.74e+003 ± 7.4e+002
Alpacas to Cash ($/year)
0 to 1500 56.0
1500 to 3000 30.5
3000 to 4560 13.5
1.6e+003 ± 1.2e+003
Sustainability
Low 68.7
High 31.3
Fiber Vicuna Price ($/k)
Restricted 100
No restricted .032
308 ± 0.21
Total Milk Production ($/year)
0 to 14500 78.5
14500 to 29000 19.5
29000 to 43500 2.00
1.07e+004 ± 8e+003
Income ($/capita/year)
0 to 100 20.0
100 to 200 26.0
200 to 300 27.7
300 to 400 19.1
400 to 500 5.81
500 to 600 1.10
600 to 700 0.22
2.2e+002 ± 1.3e+002
Total Benefits ($/year)
0 to 15000 24.7
15000 to 30000 32.8
30000 to 45000 33.6
45000 to 60000 7.19
60000 to 75000 1.36
75000 to 84000 .086
2.7e+004 ± 1.5e+004
Total Production ($/year)
0 to 23500 34.3
23500 to 47000 55.3
47000 to 70500 10.1
70500 to 94000 0.23
3e+004 ± 1.6e+004
Livestock Prod ($/year)
0 to 13000 48.0
13000 to 26000 40.3
26000 to 39000 10.4
39000 to 52000 1.22
1.5e+004 ± 1e+004
REPRESENTING "ACTUAL" LAND USE

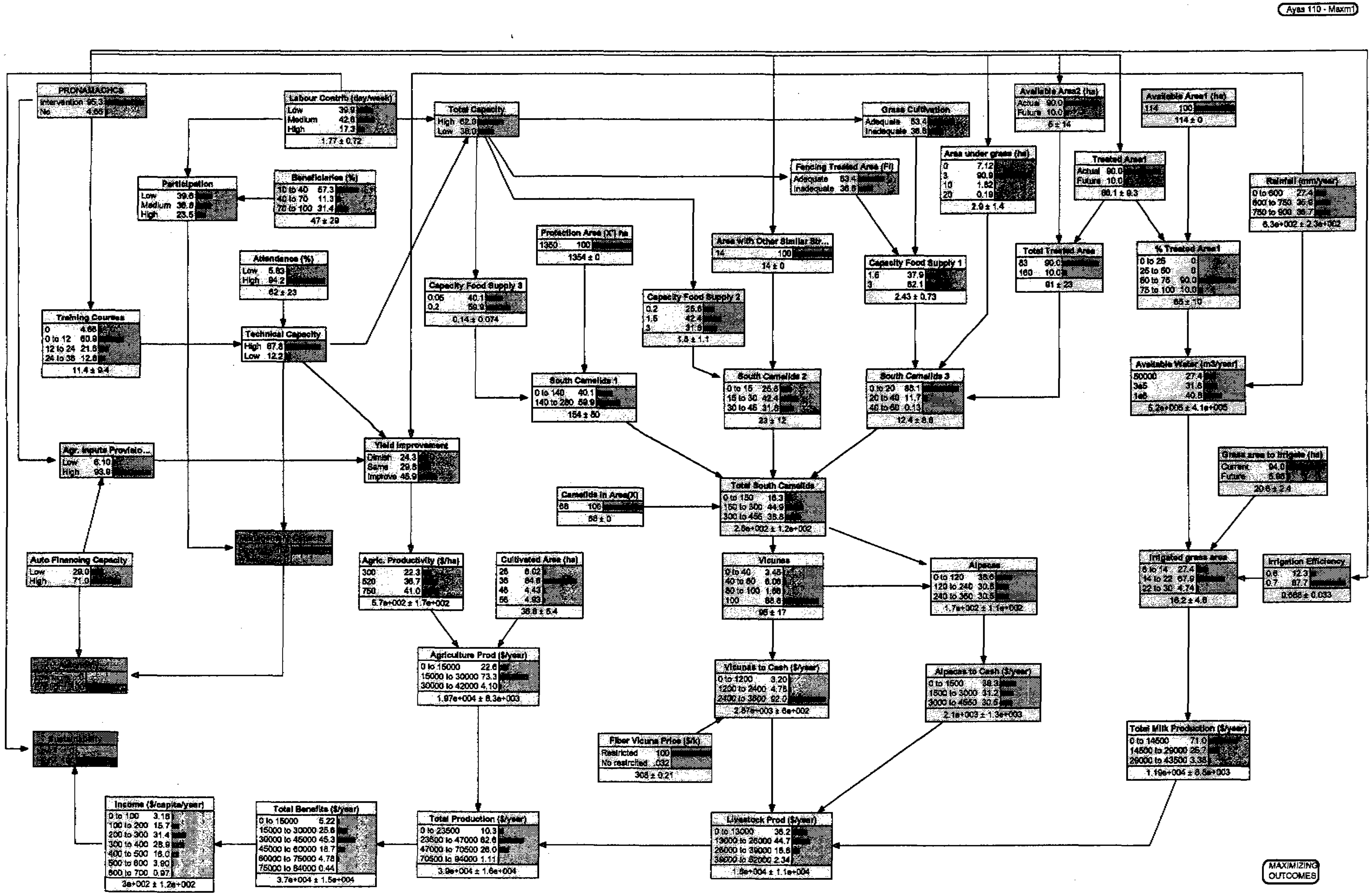
Ayas 110 - Sc3



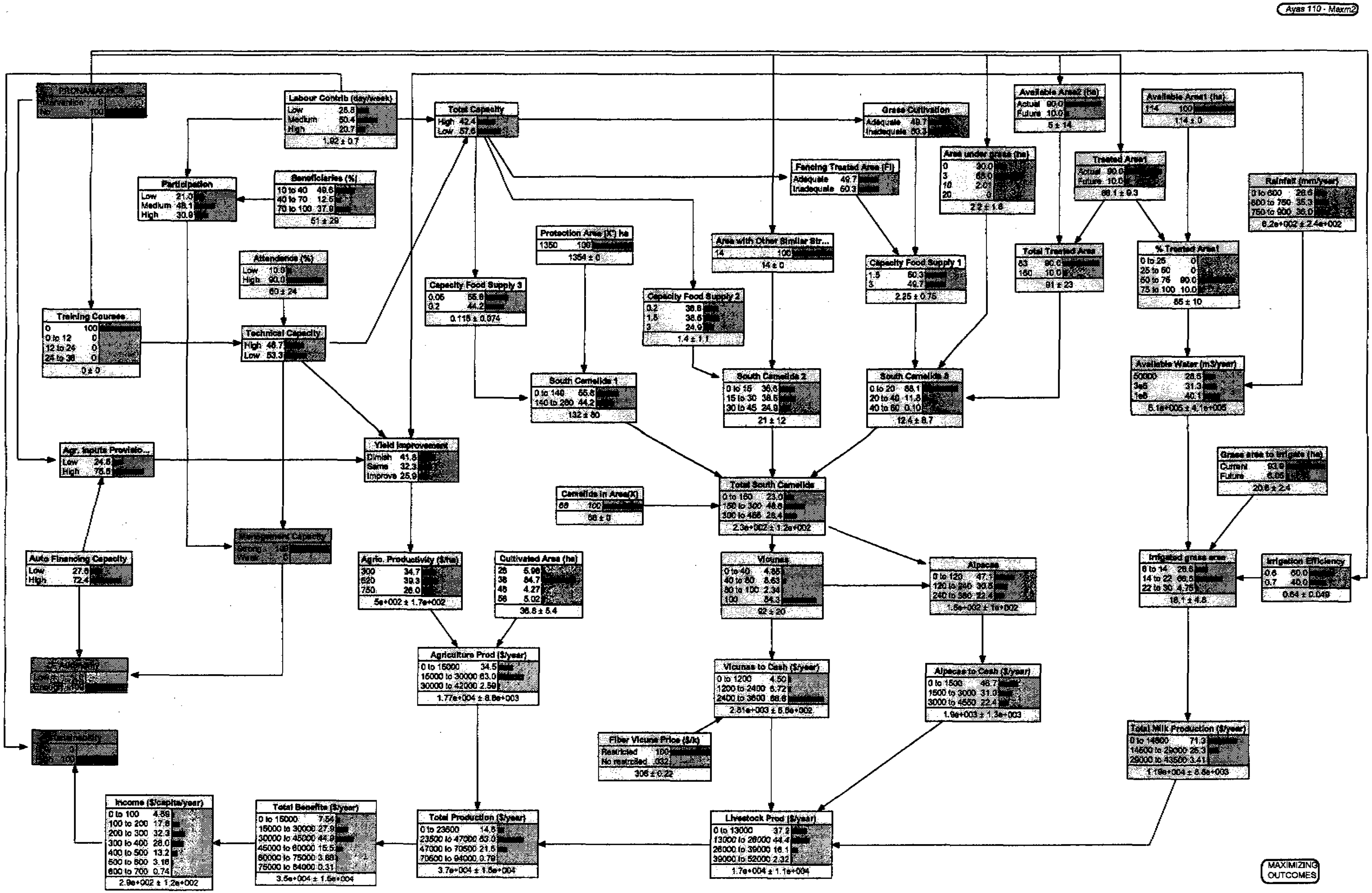
REPRESENTING "FUTURE" LAND USE



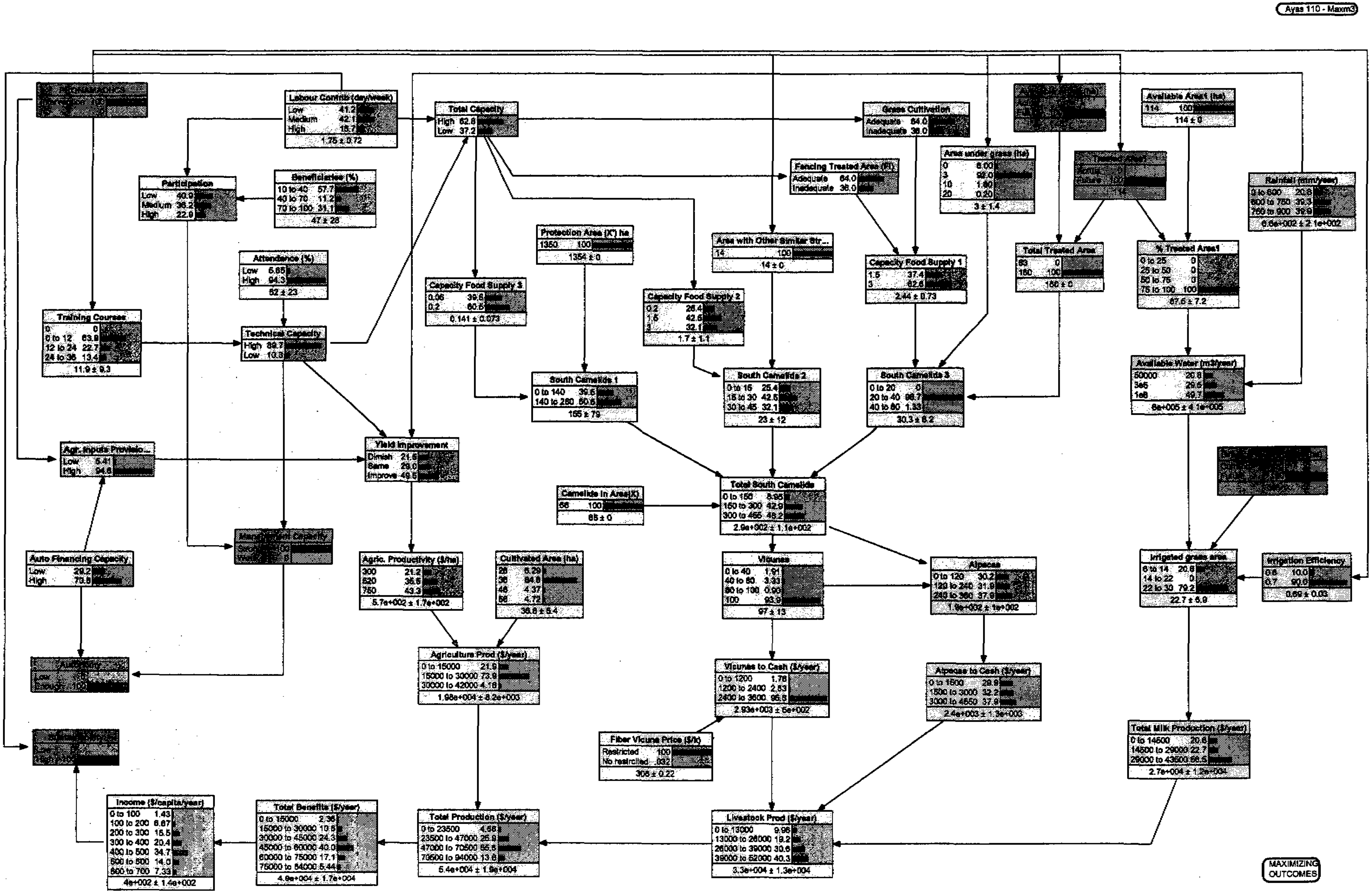
Ayas 110 - Sc4
Labour Contrib (day/week)
Total Capacity
Grass Cultivation
Available Area1 (ha)
Participation
Beneficiaries (%)
Fencing Treated Area (R)
Area under grass (ha)
Rainfall (mm/year)
Protection Area (X') ha
Area with Other Similar Str...
Attendance (%)
Capacity Food Supply 3
Capacity Food Supply 2
Capacity Food Supply 1
Total Treated Area
% Treated Area1
Training Courses
Technical Capacity
South Camelids 1
South Camelids 2
South Camelids 3
Available Water (m3/year)
Agr. Inputs Provisio...
Yield Improvement
Total South Camelids
Camelids in Area(X)
Management Capacity
Auto Financing Capacity
Agric. Productivity ($/ha)
Cultivated Area (ha)
Vicunas
Alpacas
Irrigated grass area
Irrigation Efficiency
Autonomy
Agriculture Prod ($/year)
Vicunas to Cash ($/year)
Alpacas to Cash ($/year)
Total Milk Production ($/year)
Fiber Vicuna Price ($/k)
Sustainability
Income ($/capita/year)
Total Benefits ($/year)
Total Production ($/year)
Livestock Prod ($/year)
REPRESENTING "FUTURE" LAND USE



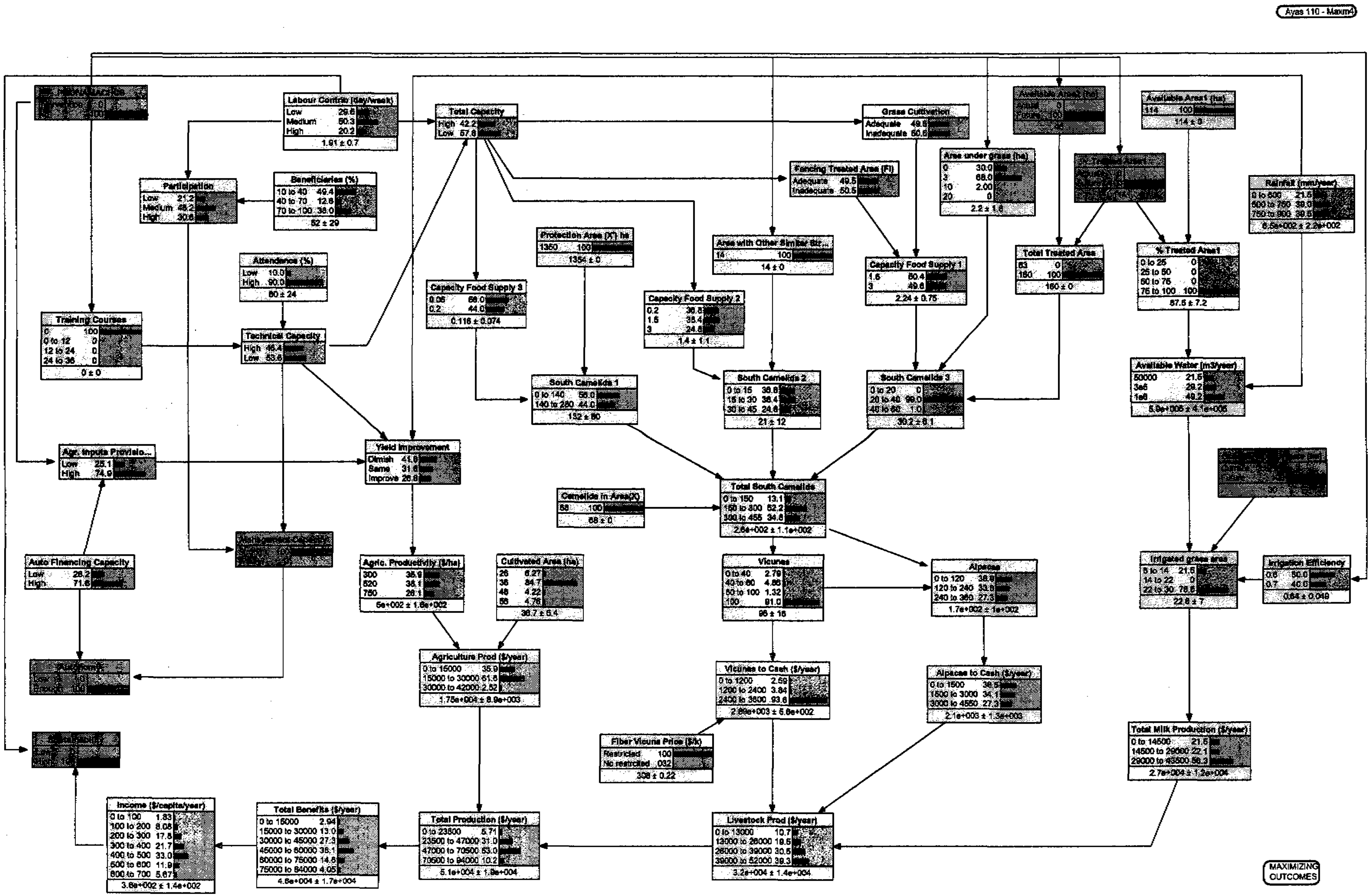
Ayas 110 - Maxm1
PRONAMACHCS
Intervention 95.3
No 4.66
Labour Contrib (day/week)
Low 39.9
Medium 42.8
High 17.3
1.77 ± 0.72
Total Capacity
High 62.0
Low 38.0
Grass Cultivation
Adequate 63.4
Inadequate 36.6
Available Area2 (ha)
Actual 90.0
Future 10.0
Available Area1 (ha)
114 100
114 ± 0
Participation
Low 39.6
Medium 36.8
High 23.5
Beneficiaries (%)
10 to 40 57.3
40 to 70 11.3
70 to 100 31.4
47 ± 29
Fencing Treated Area (FI)
Adequate 63.4
Inadequate 36.6
Area under grass (ha)
0 7.12
3 90.9
10 1.82
20 0.19
2.9 ± 1.4
Treated Area1
Actual 90.0
Future 10.0
Rainfall (mm/year)
0 to 600 27.4
600 to 750 35.9
750 to 900 36.7
6.3e+002 ± 2.3e+002
Attendance (%)
Low 5.83
High 94.2
62 ± 23
Protection Area (X) ha
1350 100
1354 ± 0
Area with Other Similar Str...
14 100
14 ± 0
Capacity Food Supply 1
1.6 37.9
3 62.1
2.43 ± 0.73
Total Treated Area
83 90.0
160 10.0
91 ± 23
% Treated Area1
0 to 25 0
25 to 50 0
50 to 75 90.0
75 to 100 10.0
65 ± 10
Capacity Food Supply 3
0.05 40.1
0.2 59.9
0.14 ± 0.074
Capacity Food Supply 2
0.2 25.8
1.5 42.4
3 31.8
1.5 ± 1.1
Training Courses
0 4.66
0 to 12 60.9
12 to 24 21.6
24 to 36 12.8
11.4 ± 9.4
Technical Capacity
High 87.8
Low 12.2
South Camelids 1
0 to 140 40.1
140 to 280 59.9
154 ± 80
South Camelids 2
0 to 15 25.8
15 to 30 42.4
30 to 45 31.8
23 ± 12
South Camelids 3
0 to 20 88.1
20 to 40 11.7
40 to 60 0.13
12.4 ± 6.8
Available Water (m3/year)
50000 27.4
3e5 31.8
1e6 40.8
5.2e+005 ± 4.1e+005
Agr. Inputs Provisio...
Low 6.10
High 93.9
Yield Improvement
Dimish 24.3
Same 29.8
Improve 45.9
Camelids in Area(X)
68 100
68 ± 0
Total South Camelids
0 to 150 18.3
150 to 300 44.9
300 to 455 36.8
2.6e+002 ± 1.2e+002
Grass area to irrigate (ha)
Current 94.0
Future 5.98
Auto Financing Capacity
Low 29.0
High 71.0
Agric. Productivity ($/ha)
300 22.3
520 36.7
750 41.0
5.7e+002 ± 1.7e+002
Cultivated Area (ha)
26 6.02
36 84.6
46 4.43
56 4.93
36.8 ± 5.4
Vicunas
0 to 40 3.45
40 to 80 6.06
80 to 100 1.88
100 88.6
95 ± 17
Alpacas
0 to 120 38.6
120 to 240 30.8
240 to 360 30.8
1.7e+002 ± 1.1e+002
Irrigated grass area
6 to 14 27.4
14 to 22 67.9
22 to 30 4.74
16.2 ± 4.8
Irrigation Efficiency
0.6 12.3
0.7 87.7
0.688 ± 0.033
Agriculture Prod ($/year)
0 to 15000 22.6
15000 to 30000 73.3
30000 to 42000 4.10
1.97e+004 ± 8.3e+003
Vicunas to Cash ($/year)
0 to 1200 3.20
1200 to 2400 4.78
2400 to 3600 92.0
Alpacas to Cash ($/year)
0 to 1500 38.3
1500 to 3000 31.2
3000 to 4550 30.5
2.1e+003 ± 1.3e+003
Fiber Vicuna Price ($/k)
Restricted 100
No restricted .032
Total Milk Production ($/year)
0 to 14500 71.0
14500 to 29000 25.7
29000 to 43500 3.35
1.19e+004 ± 8.8e+003
Income ($/capita/year)
0 to 100 3.18
100 to 200 15.7
200 to 300 31.4
300 to 400 28.9
400 to 500 16.0
500 to 600 3.90
600 to 700 0.97
3e+002 ± 1.2e+002
Total Benefits ($/year)
0 to 15000 5.22
15000 to 30000 25.6
30000 to 45000 45.3
45000 to 60000 18.7
60000 to 75000 4.78
75000 to 84000 0.44
3.7e+004 ± 1.5e+004
Total Production ($/year)
0 to 23500 10.3
23500 to 47000 62.6
47000 to 70500 26.0
70500 to 94000 1.11
3.9e+004 ± 1.6e+004
Livestock Prod ($/year)
0 to 13000 36.2
13000 to 26000 44.7
26000 to 39000 16.8
39000 to 52000 2.34
1.8e+004 ± 1.1e+004
MAXIMIZING OUTCOMES



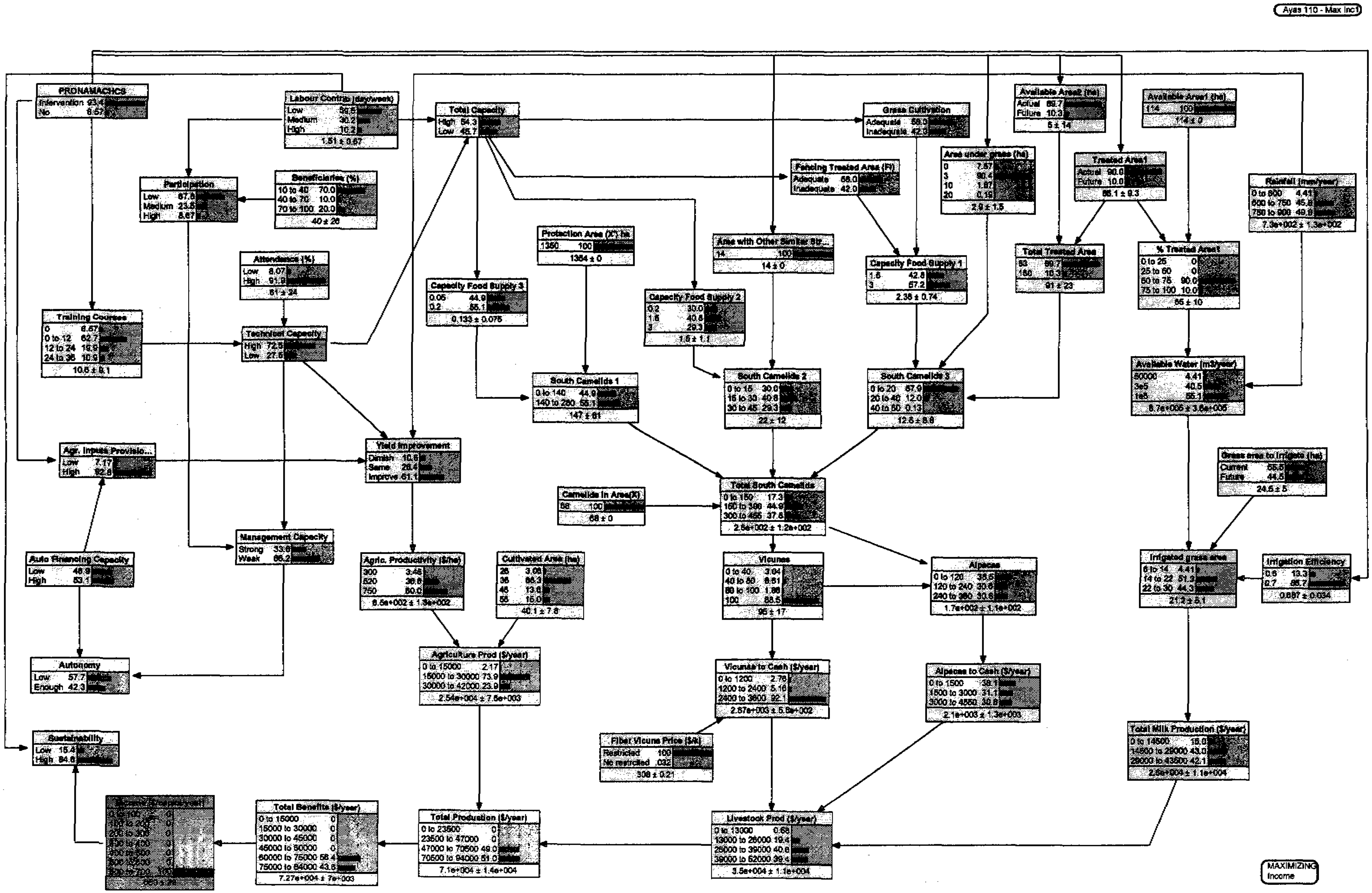
Ayas 110 - Maxm2
Labour Contrib (day/week)
Low 25.8
Medium 50.4
High 20.7
1.92 ± 0.7
Total Capacity
High 42.4
Low 57.6
Grass Cultivation
Adequate 49.7
Inadequate 50.3
Available Area2 (ha)
Actual 90.0
Future 10.0
5 ± 14
Available Area1 (ha)
114 100
114 ± 0
Participation
Low 21.0
Medium 48.1
High 30.9
Beneficiaries (%)
10 to 40 49.6
40 to 70 12.5
70 to 100 37.9
51 ± 29
Fencing Treated Area (FI)
Adequate 49.7
Inadequate 50.3
Area under grass (ha)
0 30.0
3 68.0
10 2.01
20 0
2.2 ± 1.8
Treated Area1
Actual 90.0
Future 10.0
88.1 ± 9.3
Rainfall (mm/year)
0 to 600 28.6
600 to 750 35.3
750 to 900 36.0
6.2e+002 ± 2.4e+002
Protection Area (X') ha
1350 100
1354 ± 0
Area with Other Similar Str...
14 100
14 ± 0
Attendance (%)
Low 10.0
High 90.0
80 ± 24
Capacity Food Supply 3
0.05 55.8
0.2 44.2
0.115 ± 0.074
Capacity Food Supply 2
0.2 36.6
1.5 38.5
3 24.9
1.4 ± 1.1
Capacity Food Supply 1
1.5 50.3
3 49.7
2.25 ± 0.75
Total Treated Area
83 90.0
150 10.0
91 ± 23
% Treated Area1
0 to 25 0
25 to 50 0
50 to 75 90.0
75 to 100 10.0
55 ± 10
Training Courses
0 100
0 to 12 0
12 to 24 0
24 to 36 0
0 ± 0
Technical Capacity
High 46.7
Low 53.3
South Camelids 1
0 to 140 55.8
140 to 280 44.2
132 ± 80
South Camelids 2
0 to 15 36.6
15 to 30 38.5
30 to 45 24.9
21 ± 12
South Camelids 3
0 to 20 88.1
20 to 40 11.8
40 to 60 0.10
12.4 ± 8.7
Available Water (m3/year)
50000 28.6
3e5 31.3
1e6 40.1
5.1e+005 ± 4.1e+005
Agr. Inputs Provisio...
Low 24.8
High 75.2
Yield Improvement
Diminish 41.8
Same 32.3
Improve 25.9
Total South Camelids
0 to 150 23.0
150 to 300 46.6
300 to 456 25.4
2.3e+002 ± 1.2e+002
Camelids in Area(X)
88 100
88 ± 0
Grass area to irrigate (ha)
Current 93.9
Future 6.05
20.6 ± 2.4
Auto Financing Capacity
Low 27.6
High 72.4
Agric. Productivity ($/ha)
300 34.7
520 39.3
750 26.0
5e+002 ± 1.7e+002
Cultivated Area (ha)
26 5.98
38 84.7
48 4.27
56 5.02
36.8 ± 5.4
Vicunas
0 to 40 4.85
40 to 80 8.63
80 to 100 2.34
100 84.3
92 ± 20
Alpacas
0 to 120 47.1
120 to 240 30.5
240 to 360 22.4
1.5e+002 ± 1e+002
Irrigated grass area
6 to 14 28.5
14 to 22 66.5
22 to 30 4.75
16.1 ± 4.8
Irrigation Efficiency
0.6 60.0
0.7 40.0
0.64 ± 0.049
Agriculture Prod ($/year)
0 to 15000 34.5
15000 to 30000 63.0
30000 to 42000 2.50
1.77e+004 ± 8.8e+003
Vicunas to Cash ($/year)
0 to 1200 4.50
1200 to 2400 6.72
2400 to 3600 88.8
2.81e+003 ± 6.6e+002
Alpacas to Cash ($/year)
0 to 1500 46.7
1500 to 3000 31.0
3000 to 4500 22.4
1.9e+003 ± 1.3e+003
Fiber Vicuna Price ($/k)
Restricted 100
No restricted .032
306 ± 0.22
Total Milk Production ($/year)
0 to 14500 71.3
14500 to 29000 25.3
29000 to 43500 3.41
1.19e+004 ± 8.8e+003
Income ($/capita/year)
0 to 100 4.59
100 to 200 17.8
200 to 300 32.3
300 to 400 28.0
400 to 500 13.2
500 to 600 3.16
600 to 700 0.74
2.9e+002 ± 1.2e+002
Total Benefits ($/year)
0 to 15000 7.54
15000 to 30000 27.9
30000 to 45000 44.9
45000 to 60000 15.5
60000 to 75000 3.88
75000 to 84000 0.31
3.5e+004 ± 1.5e+004
Total Production ($/year)
0 to 23500 14.8
23500 to 47000 63.0
47000 to 70500 21.5
70500 to 94000 0.79
3.7e+004 ± 1.8e+004
Livestock Prod ($/year)
0 to 13000 37.2
13000 to 26000 44.4
26000 to 39000 16.1
39000 to 52000 2.32
1.7e+004 ± 1.1e+004
MAXIMIZING OUTCOMES

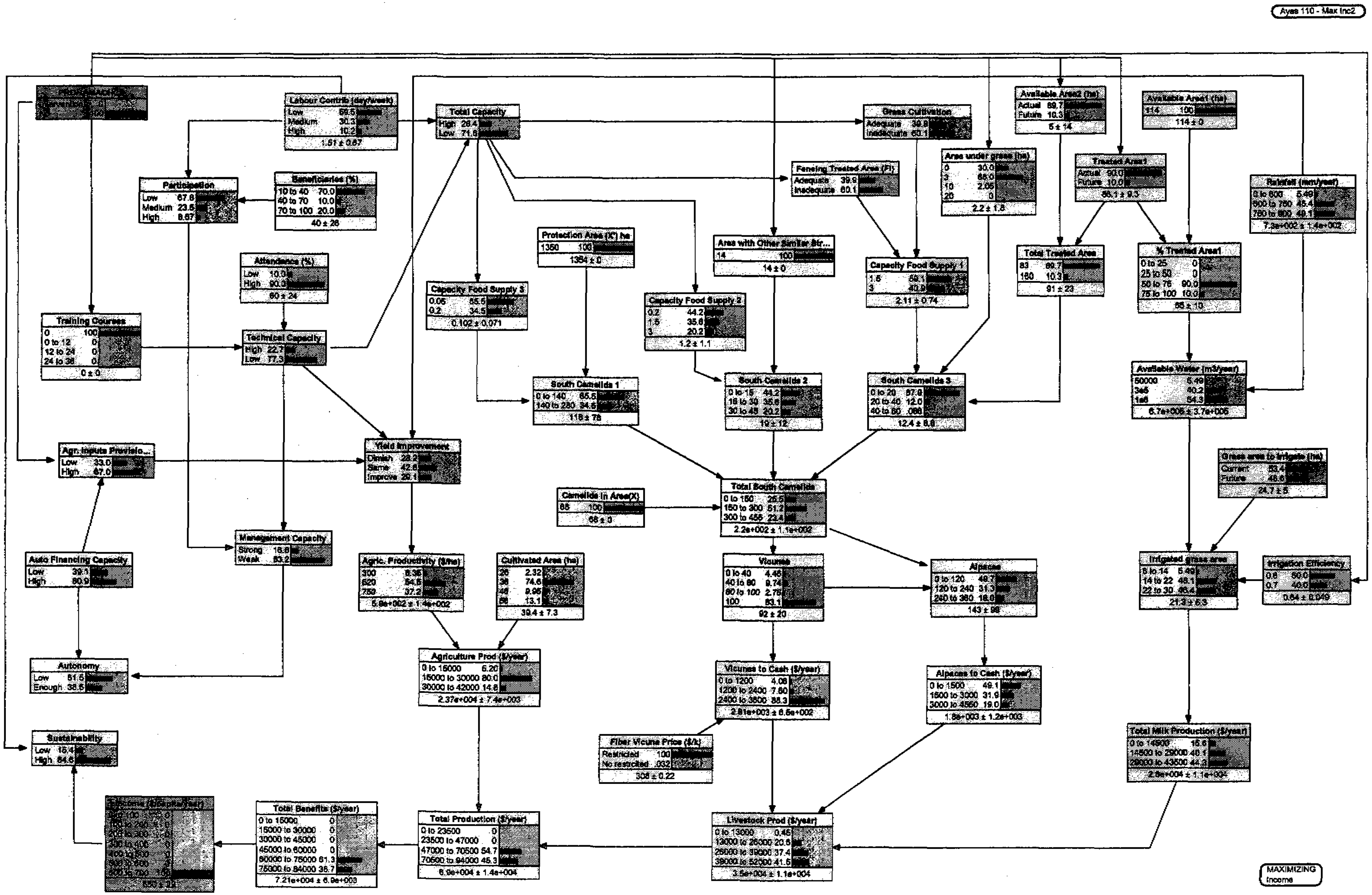


Ayas 110 - Maxm3
Labour Contrib (day/week)
Low 41.2
Medium 42.1
High 15.7
1.75 ± 0.72
Total Capacity
High 62.8
Low 37.2
Grass Cultivation
Adequate 64.0
Inadequate 36.0
Available Area1 (ha)
114 100
114 ± 0
Participation
Low 40.9
Medium 36.2
High 22.9
Beneficiaries (%)
10 to 40 57.7
40 to 70 11.2
70 to 100 31.1
47 ± 28
Fencing Treated Area (FI)
Adequate 64.0
Inadequate 36.0
Area under grass (ha)
0 6.00
3 92.0
10 1.80
20 0.20
3 ± 1.4
Rainfall (mm/year)
0 to 600 20.8
600 to 750 39.3
750 to 900 39.9
6.6e+002 ± 2.1e+002
Protection Area (X') ha
1350 100
1354 ± 0
Area with Other Similar Str...
14 100
14 ± 0
Attendance (%)
Low 5.65
High 94.3
82 ± 23
Capacity Food Supply 1
1.5 37.4
3 62.6
2.44 ± 0.73
Total Treated Area
83 0
150 100
150 ± 0
% Treated Area1
0 to 25 0
25 to 50 0
50 to 75 0
75 to 100 100
87.5 ± 7.2
Capacity Food Supply 3
0.06 39.5
0.2 60.5
0.141 ± 0.073
Capacity Food Supply 2
0.2 26.4
1.5 42.5
3 32.1
1.7 ± 1.1
Training Courses
0 0
0 to 12 63.9
12 to 24 22.7
24 to 36 13.4
11.9 ± 9.3
Technical Capacity
High 89.7
Low 10.3
South Camelids 1
0 to 140 39.5
140 to 280 60.5
165 ± 79
South Camelids 2
0 to 15 25.4
15 to 30 42.5
30 to 45 32.1
23 ± 12
South Camelids 3
0 to 20 0
20 to 40 98.7
40 to 60 1.33
30.3 ± 6.2
Available Water (m3/year)
50000 20.8
3e5 29.5
1e6 49.7
6e+005 ± 4.1e+005
Agr. Inputs Provisio...
Low 5.41
High 94.6
Yield Improvement
Diminish 21.6
Same 29.0
Improve 49.5
Total South Camelids
0 to 150 8.95
150 to 300 42.9
300 to 465 48.2
2.9e+002 ± 1.1e+002
Camelids in Area(X)
66 100
66 ± 0
Auto Financing Capacity
Low 29.2
High 70.8
Agric. Productivity ($/ha)
300 21.2
520 35.5
750 43.3
5.7e+002 ± 1.7e+002
Cultivated Area (ha)
28 6.29
36 84.6
46 4.37
56 4.72
36.8 ± 6.4
Vicunas
0 to 40 1.91
40 to 80 3.33
80 to 100 0.90
100 93.9
97 ± 13
Alpacas
0 to 120 30.2
120 to 240 31.9
240 to 360 37.9
1.9e+002 ± 1e+002
Irrigated grass area
6 to 14 20.8
14 to 22 0
22 to 30 79.2
22.7 ± 6.9
Irrigation Efficiency
0.6 10.0
0.7 90.0
0.69 ± 0.03
Agriculture Prod ($/year)
0 to 15000 21.9
15000 to 30000 73.9
30000 to 42000 4.18
1.98e+004 ± 8.2e+003
Vicunas to Cash ($/year)
0 to 1200 1.76
1200 to 2400 2.63
2400 to 3600 95.6
2.93e+003 ± 5e+002
Alpacas to Cash ($/year)
0 to 1500 29.9
1500 to 3000 32.2
3000 to 4550 37.9
2.4e+003 ± 1.3e+003
Fiber Vicuna Price ($/k)
Restricted 100
No restricted .032
308 ± 0.22
Total Milk Production ($/year)
0 to 14500 20.8
14500 to 29000 22.7
29000 to 43500 56.5
2.7e+004 ± 1.2e+004
Income ($/capita/year)
0 to 100 1.43
100 to 200 6.67
200 to 300 15.5
300 to 400 20.4
400 to 500 34.7
500 to 600 14.0
600 to 700 7.33
4e+002 ± 1.4e+002
Total Benefits ($/year)
0 to 15000 2.36
15000 to 30000 10.6
30000 to 45000 24.3
45000 to 60000 40.0
60000 to 75000 17.1
75000 to 84000 5.44
4.9e+004 ± 1.7e+004
Total Production ($/year)
0 to 23500 4.66
23500 to 47000 25.9
47000 to 70500 55.6
70500 to 94000 13.8
5.4e+004 ± 1.9e+004
Livestock Prod ($/year)
0 to 13000 9.96
13000 to 26000 19.2
26000 to 39000 30.6
39000 to 52000 40.3
3.3e+004 ± 1.3e+004
MAXIMIZING OUTCOMES

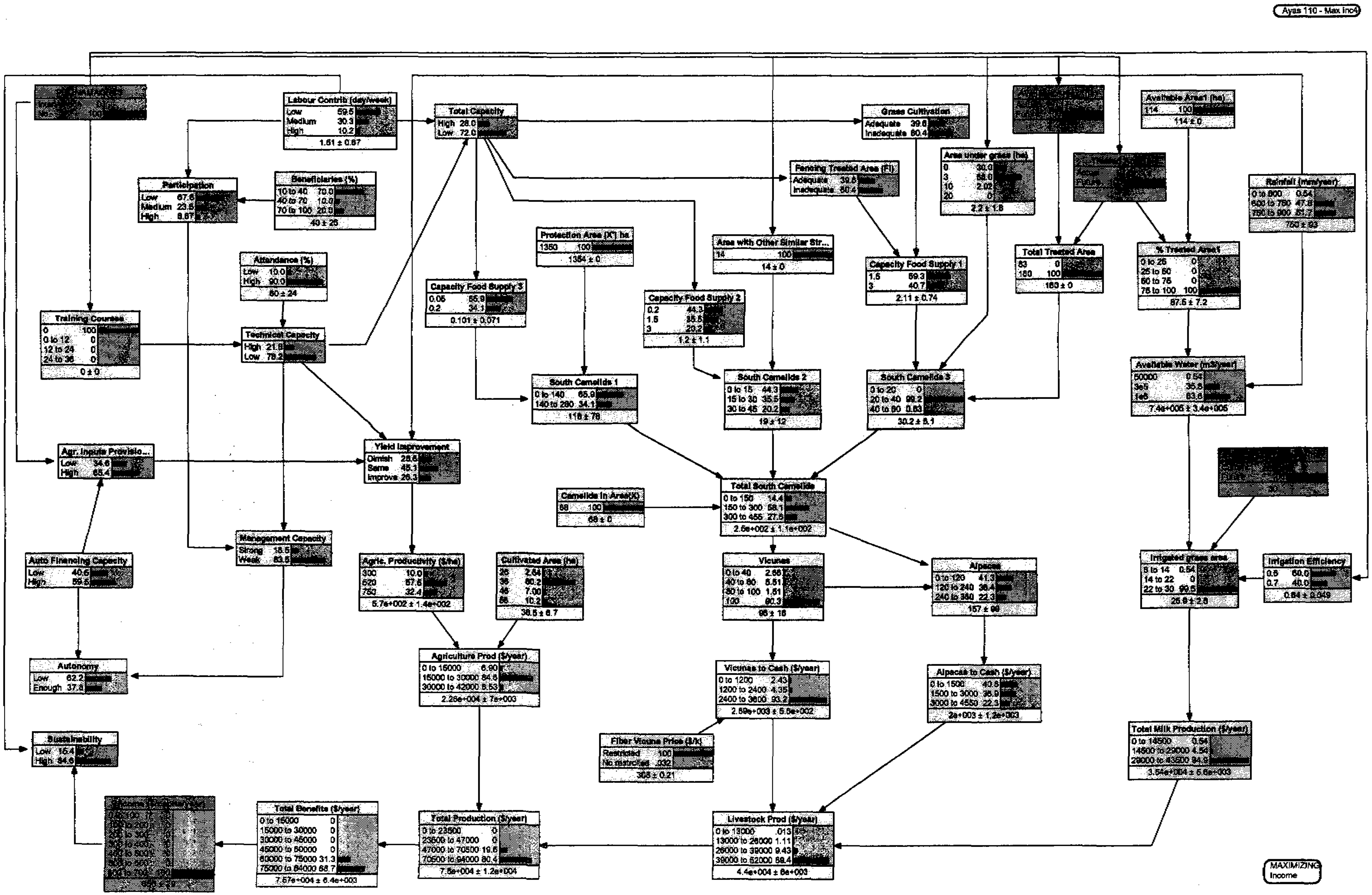


Ayas 110 - Maxm4
Labour Contrib (day/week)
Low 29.6
Medium 50.3
High 20.2
1.91 ± 0.7
Total Capacity
High 42.2
Low 57.8
Grass Cultivation
Adequate 49.5
Inadequate 50.5
Available Area1 (ha)
114 100
114 ± 0
Participation
Low 21.2
Medium 48.2
High 30.6
Beneficiaries (%)
10 to 40 49.4
40 to 70 12.6
70 to 100 38.0
52 ± 29
Fencing Treated Area (FI)
Adequate 49.5
Inadequate 50.5
Area under grass (ha)
0 30.0
3 68.0
10 2.00
20 0
2.2 ± 1.8
Rainfall (mm/year)
0 to 600 21.5
600 to 750 39.0
750 to 900 39.5
6.6e+002 ± 2.2e+002
Attendance (%)
Low 10.0
High 90.0
80 ± 24
Protection Area (X) ha
1350 100
1354 ± 0
Area with Other Similar Str...
14 100
14 ± 0
Capacity Food Supply 1
1.5 50.4
3 49.6
2.24 ± 0.75
Total Treated Area
83 0
160 100
160 ± 0
% Treated Area1
0 to 25 0
25 to 50 0
50 to 75 0
75 to 100 100
87.5 ± 7.2
Training Courses
0 100
0 to 12 0
12 to 24 0
24 to 36 0
0 ± 0
Technical Capacity
High 46.4
Low 53.6
Capacity Food Supply 3
0.06 56.0
0.2 44.0
0.116 ± 0.074
Capacity Food Supply 2
0.2 36.8
1.5 38.4
3 24.8
1.4 ± 1.1
South Camelids 1
0 to 140 56.0
140 to 280 44.0
132 ± 80
South Camelids 2
0 to 15 36.8
15 to 30 38.4
30 to 45 24.8
21 ± 12
South Camelids 3
0 to 20 0
20 to 40 99.0
40 to 60 1.0
30.2 ± 6.1
Available Water (m3/year)
50000 21.5
3e6 29.2
1e6 49.2
5.9e+005 ± 4.1e+005
Agr. Inputs Provisio...
Low 25.1
High 74.9
Yield Improvement
Diminish 41.6
Same 31.6
Improve 26.8
Camelids in Area(X)
88 100
88 ± 0
Total South Camelids
0 to 150 13.1
150 to 300 52.2
300 to 455 34.8
2.6e+002 ± 1.1e+002
Auto Financing Capacity
Low 28.2
High 71.8
Agric. Productivity ($/ha)
300 35.9
520 38.1
750 26.1
5e+002 ± 1.6e+002
Cultivated Area (ha)
26 6.27
36 84.7
46 4.22
56 4.78
36.7 ± 5.4
Vicunas
0 to 40 2.79
40 to 60 4.86
60 to 100 1.32
100 91.0
96 ± 16
Alpacas
0 to 120 38.9
120 to 240 33.8
240 to 360 27.3
1.7e+002 ± 1e+002
Irrigated grass area
5 to 14 21.5
14 to 22 0
22 to 30 78.5
22.8 ± 7
Irrigation Efficiency
0.6 60.0
0.7 40.0
0.64 ± 0.049
Agriculture Prod ($/year)
0 to 15000 35.9
15000 to 30000 61.6
30000 to 42000 2.52
1.75e+004 ± 8.9e+003
Vicunas to Cash ($/year)
0 to 1200 2.59
1200 to 2400 3.84
2400 to 3600 93.6
2.89e+003 ± 5.6e+002
Alpacas to Cash ($/year)
0 to 1500 38.5
1500 to 3000 34.1
3000 to 4550 27.3
2.1e+003 ± 1.3e+003
Fiber Vicuna Price ($/k)
Restricted 100
No restricted .032
308 ± 0.22
Total Milk Production ($/year)
0 to 14500 21.5
14500 to 29000 22.1
29000 to 43500 56.3
2.7e+004 ± 1.2e+004
Income ($/capita/year)
0 to 100 1.83
100 to 200 8.08
200 to 300 17.8
300 to 400 21.7
400 to 500 33.0
500 to 600 11.9
600 to 700 5.67
3.8e+002 ± 1.4e+002
Total Benefits ($/year)
0 to 15000 2.94
15000 to 30000 13.0
30000 to 45000 27.3
45000 to 60000 38.1
60000 to 75000 14.8
75000 to 84000 4.05
4.6e+004 ± 1.7e+004
Total Production ($/year)
0 to 23500 5.71
23500 to 47000 31.0
47000 to 70500 53.0
70500 to 94000 10.2
5.1e+004 ± 1.9e+004
Livestock Prod ($/year)
0 to 13000 10.7
13000 to 26000 19.6
26000 to 39000 30.5
39000 to 52000 39.3
3.2e+004 ± 1.4e+004
MAXIMIZING OUTCOMES

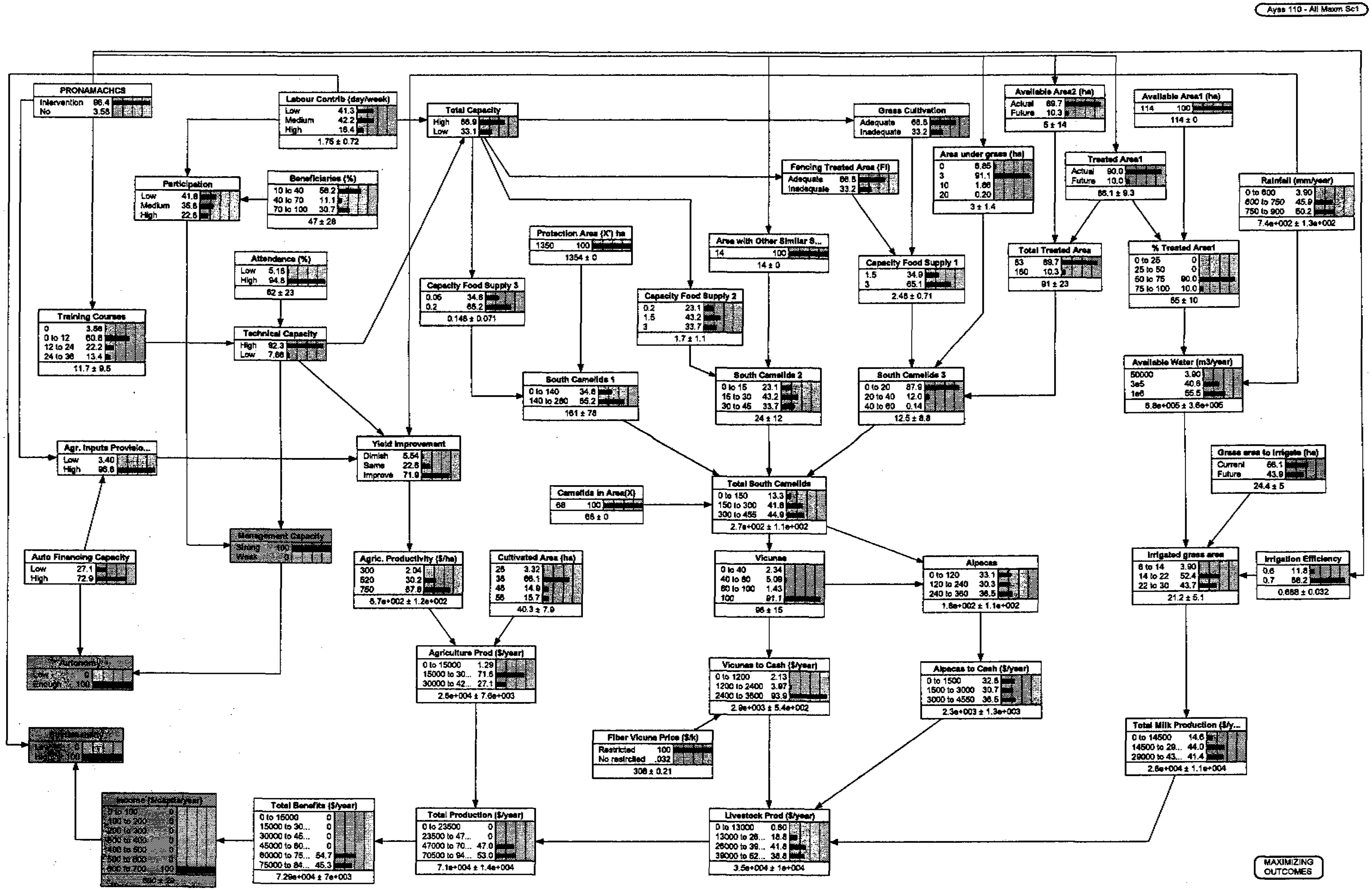

Ayas 110 - Max Inc1
PRONAMACHCS
Intervention 93.4
No 6.57
Labour Contrib (day/week)
Low
Medium
High
1.51 ± 0.87
Total Capacity
High 54.3
Low 45.7
Grass Cultivation
Adequate 58.0
Inadequate 42.0
Available Area2 (ha)
Actual 89.7
Future 10.3
5 ± 14
Available Area1 (ha)
114 100
114 ± 0
Participation
Low 67.8
Medium 23.5
High 8.67
Beneficiaries (%)
10 to 40 70.0
40 to 70 10.0
70 to 100 20.0
40 ± 26
Fencing Treated Area (FI)
Adequate 58.0
Inadequate 42.0
Area under grass (ha)
Treated Area1
Actual 90.0
Future 10.0
Rainfall (mm/year)
0 to 600 4.41
600 to 750 45.8
750 to 900 49.8
Protection Area (X') ha
1350 100
1354 ± 0
Area with Other Similar Str...
14 100
14 ± 0
Attendance (%)
Low 8.07
High 91.9
Capacity Food Supply 3
0.05 44.9
0.2 55.1
0.133 ± 0.075
Capacity Food Supply 2
Capacity Food Supply 1
1.5 42.8
3 57.2
2.36 ± 0.74
Total Treated Area
% Treated Area1
0 to 25 0
25 to 50 0
50 to 75 90.0
75 to 100 10.0
65 ± 10
Training Courses
0 6.57
0 to 12 62.7
12 to 24 19.9
24 to 36 10.9
10.5 ± 9.1
Technical Capacity
High 72.5
Low 27.5
South Camelids 1
0 to 140 44.9
140 to 280 55.1
147 ± 61
South Camelids 2
South Camelids 3
Available Water (m3/year)
Agr. Inputs Provisio...
Low 7.17
High 92.8
Yield Improvement
Diminish 10.6
Same 28.4
Improve 61.1
Camelids in Area(X)
68 100
68 ± 0
Total South Camelids
Grass area to Irrigate (ha)
Current
Future
24.5 ± 5
Management Capacity
Strong 33.8
Weak 66.2
Auto Financing Capacity
Low 46.9
High 53.1
Agric. Productivity ($/ha)
300 3.45
520 36.6
750 60.0
Cultivated Area (ha)
Vicunas
Alpacas
Irrigated grass area
Irrigation Efficiency
0.6 13.3
0.7 86.7
0.687 ± 0.034
Autonomy
Low 57.7
Enough 42.3
Agriculture Prod ($/year)
Vicunas to Cash ($/year)
Alpacas to Cash ($/year)
Fiber Vicuna Price ($/k)
Restricted 100
No restricted .032
Total Milk Production ($/year)
Sustainability
Low 15.4
High 84.6
Total Benefits ($/year)
0 to 15000 0
15000 to 30000 0
30000 to 45000 0
45000 to 60000 0
60000 to 75000 56.4
75000 to 84000 43.6
7.27e+004 ± 7e+003
Total Production ($/year)
0 to 23500 0
23500 to 47000 0
47000 to 70500 49.0
70500 to 94000 51.0
7.1e+004 ± 1.4e+004
Livestock Prod ($/year)
0 to 13000 0.68
13000 to 26000 19.4
26000 to 39000 40.6
39000 to 52000 39.4
3.5e+004 ± 1.1e+004
MAXIMIZING
Income



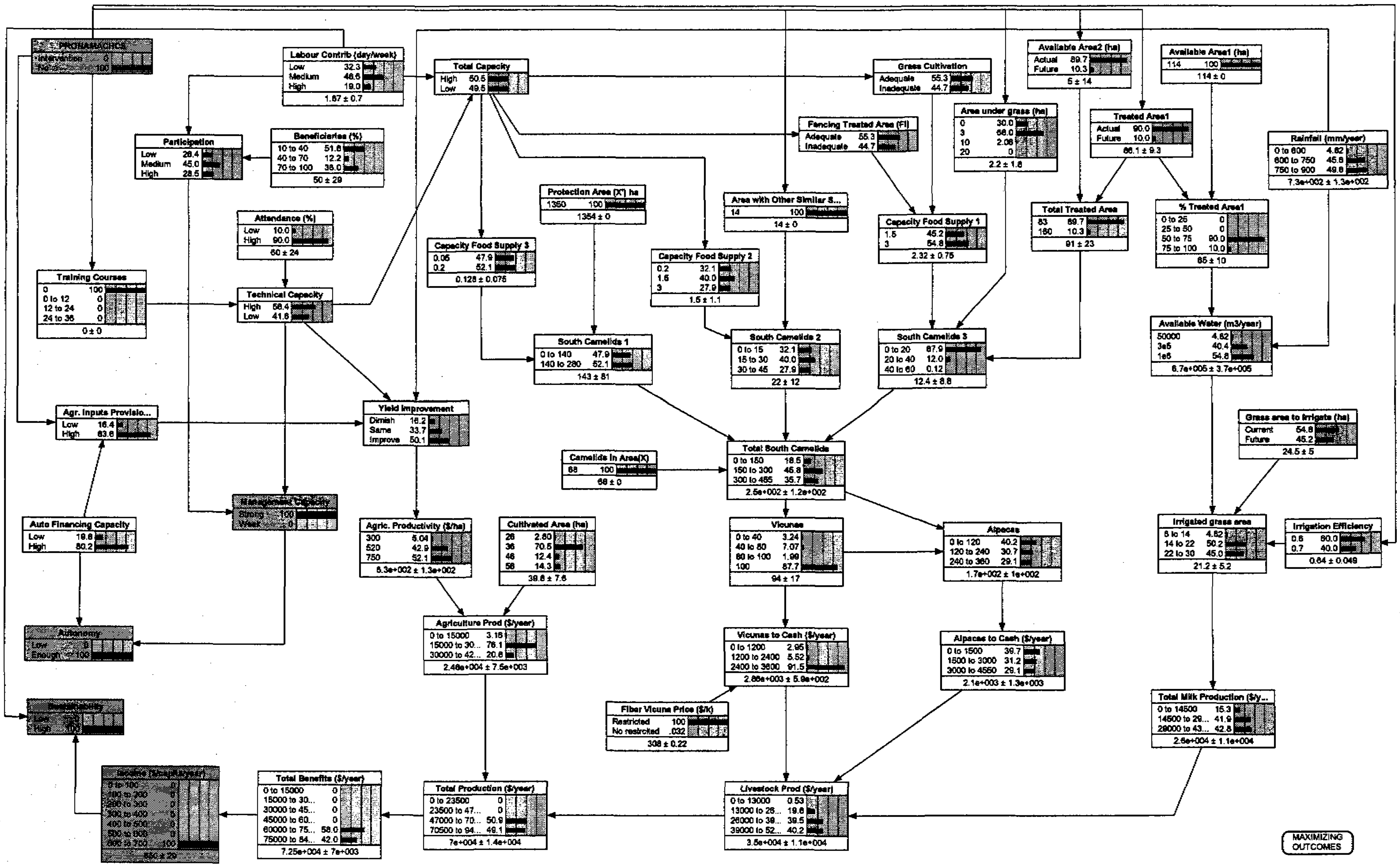
Ayes 110 - Max Inc2
Labour Contrib (day/week)
Total Capacity
Grass Cultivation
Available Area2 (ha)
Available Area1 (ha)
Participation
Beneficiaries (%)
Fencing Treated Area (F)
Area under grass (ha)
Treated Area1
Rainfall (mm/year)
Attendance (%)
Protection Area (X') ha
Area with Other Similar Str...
Capacity Food Supply 1
Total Treated Area
% Treated Area1
Capacity Food Supply 3
Capacity Food Supply 2
Training Courses
Technical Capacity
South Camelids 1
South Camelids 2
South Camelids 3
Available Water (m3/year)
Agr. Inputs Provisio...
Yield Improvement
Grass area to irrigate (ha)
Camelids in Area(X)
Total South Camelids
Auto Financing Capacity
Management Capacity
Agric. Productivity ($/ha)
Cultivated Area (ha)
Vicunas
Alpacas
Irrigated grass area
Irrigation Efficiency
Autonomy
Agriculture Prod ($/year)
Vicunas to Cash ($/year)
Alpacas to Cash ($/year)
Sustainability
Fiber Vicuna Price ($/k)
Total Milk Production ($/year)
Total Benefits ($/year)
Total Production ($/year)
Livestock Prod ($/year)
MAXIMIZING
Income



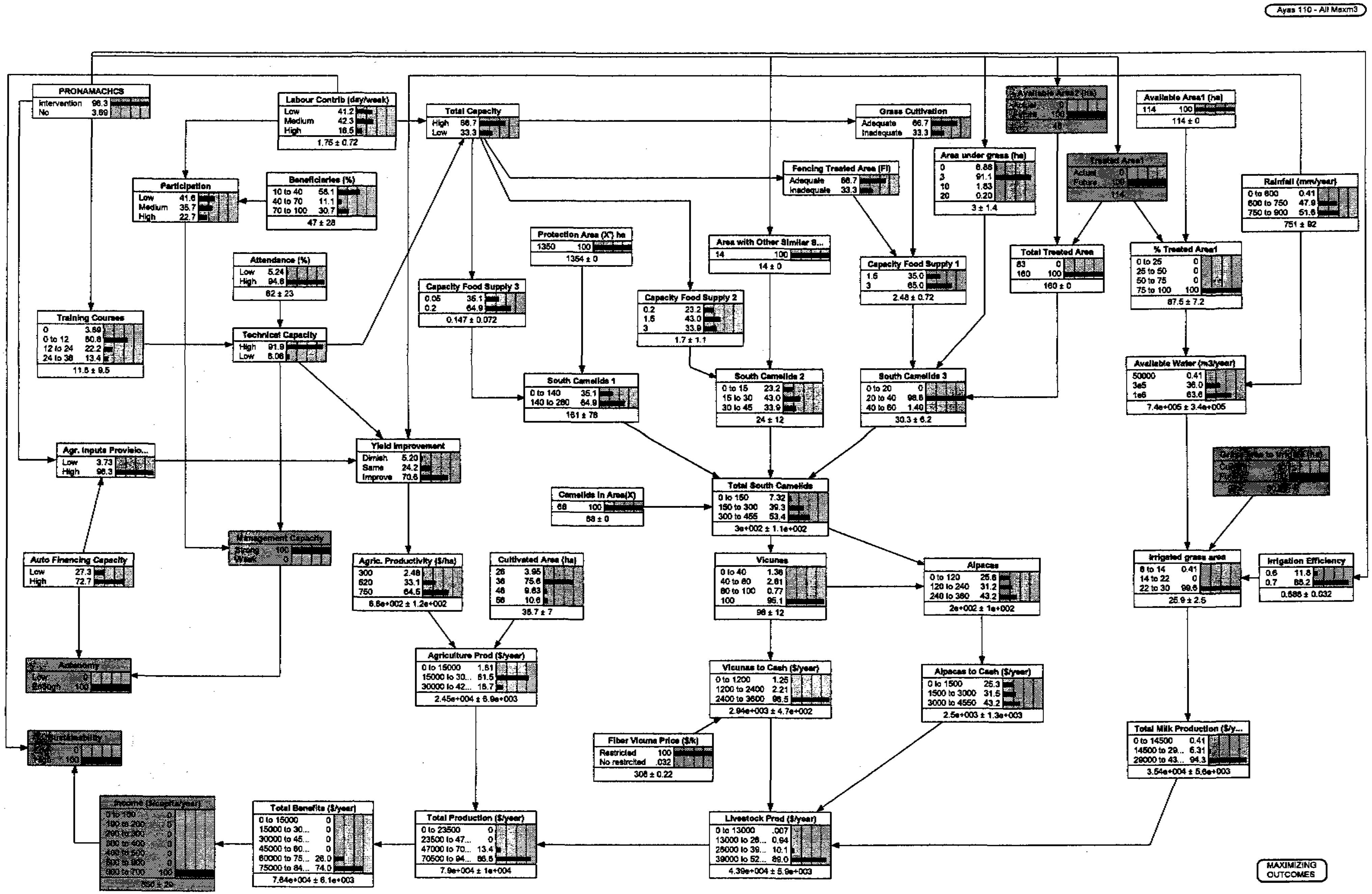
Ayas 110 - Max Inc4
Labour Contrib (day/week)
Low 59.5
Medium 30.3
High 10.2
1.61 ± 0.67
Total Capacity
High 28.0
Low 72.0
Grass Cultivation
Adequate 39.6
Inadequate 60.4
Available Area1 (ha)
114 100
114 ± 0
Participation
Low 67.6
Medium 23.5
High 8.87
Beneficiaries (%)
10 to 40 70.0
40 to 70 10.0
70 to 100 20.0
40 ± 26
Fencing Treated Area (FI)
Adequate 39.6
Inadequate 60.4
Area under grass (ha)
0 30.0
3 68.0
10 2.02
20 0
2.2 ± 1.8
Rainfall (mm/year)
0 to 600 0.54
600 to 750 47.8
750 to 900 51.7
750 ± 93
Protection Area (X') ha
1350 100
1354 ± 0
Area with Other Similar Str...
14 100
14 ± 0
Capacity Food Supply 1
1.5 59.3
3 40.7
2.11 ± 0.74
Total Treated Area
83 0
180 100
180 ± 0
% Treated Area1
0 to 25 0
25 to 50 0
50 to 75 0
75 to 100 100
87.5 ± 7.2
Attendance (%)
Low 10.0
High 90.0
80 ± 24
Capacity Food Supply 3
0.05 65.9
0.2 34.1
0.101 ± 0.071
Capacity Food Supply 2
0.2 44.3
1.5 35.5
3 20.2
1.2 ± 1.1
Training Courses
0 100
0 to 12 0
12 to 24 0
24 to 36 0
0 ± 0
Technical Capacity
High 21.8
Low 78.2
South Camelids 1
0 to 140 65.9
140 to 280 34.1
118 ± 78
South Camelids 2
0 to 15 44.3
15 to 30 35.5
30 to 45 20.2
19 ± 12
South Camelids 3
0 to 20 0
20 to 40 99.2
40 to 60 0.83
30.2 ± 5.1
Available Water (m3/year)
50000 0.54
3e5 35.8
1e6 63.6
7.4e+005 ± 3.4e+005
Agr. Inputs Provisio...
Low 34.6
High 65.4
Yield Improvement
Dimish 28.6
Same 45.1
Improve 26.3
Total South Camelids
0 to 150 14.4
150 to 300 58.1
300 to 455 27.5
2.5e+002 ± 1.1e+002
Camelids in Area(X)
68 100
68 ± 0
Management Capacity
Strong 16.5
Weak 83.5
Auto Financing Capacity
Low 40.5
High 59.5
Agric. Productivity ($/ha)
300 10.0
520 57.6
750 32.4
5.7e+002 ± 1.4e+002
Cultivated Area (ha)
25 2.64
35 80.2
45 7.00
55 10.2
36.5 ± 6.7
Vicunas
0 to 40 2.66
40 to 60 5.51
60 to 100 1.51
100 90.3
96 ± 18
Alpacas
0 to 120 41.3
120 to 240 36.4
240 to 380 22.3
157 ± 98
Irrigated grass area
8 to 14 0.54
14 to 22 0
22 to 30 99.5
25.9 ± 2.6
Irrigation Efficiency
0.6 60.0
0.7 40.0
0.64 ± 0.049
Autonomy
Low 62.2
Enough 37.8
Agriculture Prod ($/year)
0 to 15000 6.90
15000 to 30000 84.6
30000 to 42000 8.53
2.26e+004 ± 7e+003
Vicunas to Cash ($/year)
0 to 1200 2.43
1200 to 2400 4.35
2400 to 3600 93.2
2.59e+003 ± 5.5e+002
Alpacas to Cash ($/year)
0 to 1500 40.8
1500 to 3000 36.9
3000 to 4550 22.3
2e+003 ± 1.2e+003
Total Milk Production ($/year)
0 to 14500 0.54
14500 to 29000 4.54
29000 to 43500 94.9
3.54e+004 ± 5.5e+003
Fiber Vicuna Price ($/k)
Restricted 100
No restricted .032
308 ± 0.21
Sustainability
Low 15.4
High 84.6
Total Benefits ($/year)
0 to 15000 0
15000 to 30000 0
30000 to 45000 0
45000 to 60000 0
60000 to 75000 31.3
75000 to 84000 68.7
7.67e+004 ± 6.4e+003
Total Production ($/year)
0 to 23500 0
23500 to 47000 0
47000 to 70500 19.6
70500 to 94000 80.4
7.8e+004 ± 1.2e+004
Livestock Prod ($/year)
0 to 13000 .013
13000 to 26000 1.11
26000 to 39000 9.43
39000 to 52000 89.4
4.4e+004 ± 6e+003
MAXIMIZING
Income


Ayas 110 - All Maxm Sc1
PRONAMACHCS
Intervention 96.4
No 3.58
Labour Contrib (day/week)
Low 41.3
Medium 42.2
High 16.4
1.75 ± 0.72
Total Capacity
High 66.9
Low 33.1
Grass Cultivation
Adequate 66.8
Inadequate 33.2
Available Area2 (ha)
Actual 89.7
Future 10.3
5 ± 14
Available Area1 (ha)
114 100
114 ± 0
Participation
Low 41.6
Medium 35.8
High 22.6
Beneficiaries (%)
10 to 40 58.2
40 to 70 11.1
70 to 100 30.7
47 ± 28
Fencing Treated Area (FI)
Adequate 66.8
Inadequate 33.2
Area under grass (ha)
0 6.85
3 91.1
10 1.86
20 0.20
3 ± 1.4
Treated Area1
Actual 90.0
Future 10.0
85.1 ± 9.3
Rainfall (mm/year)
0 to 600 3.90
600 to 750 45.9
750 to 900 50.2
7.4e+002 ± 1.3e+002
Protection Area (X') ha
1350 100
1354 ± 0
Area with Other Similar S...
14 100
14 ± 0
Attendence (%)
Low 5.16
High 94.8
62 ± 23
Capacity Food Supply 3
0.05 34.8
0.2 65.2
0.148 ± 0.071
Capacity Food Supply 2
0.2 23.1
1.5 43.2
3 33.7
1.7 ± 1.1
Capacity Food Supply 1
1.5 34.9
3 65.1
2.48 ± 0.71
Total Treated Area
83 89.7
160 10.3
91 ± 23
% Treated Area1
0 to 25 0
25 to 50 0
50 to 75 90.0
75 to 100 10.0
65 ± 10
Training Courses
0 3.56
0 to 12 60.8
12 to 24 22.2
24 to 36 13.4
11.7 ± 9.5
Technical Capacity
High 92.3
Low 7.68
South Camelids 1
0 to 140 34.8
140 to 280 65.2
161 ± 78
South Camelids 2
0 to 15 23.1
15 to 30 43.2
30 to 45 33.7
24 ± 12
South Camelids 3
0 to 20 87.9
20 to 40 12.0
40 to 60 0.14
12.5 ± 8.8
Available Water (m3/year)
50000 3.90
3e5 40.6
1e6 55.5
6.8e+005 ± 3.6e+005
Agr. Inputs Provisio...
Low 3.40
High 96.6
Yield Improvement
Dimish 5.54
Same 22.6
Improve 71.9
Camelids in Area(X)
68 100
68 ± 0
Total South Camelids
0 to 150 13.3
150 to 300 41.8
300 to 455 44.9
2.7e+002 ± 1.1e+002
Grass area to irrigate (ha)
Current 56.1
Future 43.9
24.4 ± 5
Management Capacity
Strong 100
Weak 0
Auto Financing Capacity
Low 27.1
High 72.9
Agric. Productivity ($/ha)
300 2.04
520 30.2
750 67.8
6.7e+002 ± 1.2e+002
Cultivated Area (ha)
25 3.32
35 66.1
45 14.9
55 15.7
40.3 ± 7.9
Vicunas
0 to 40 2.34
40 to 80 5.09
80 to 100 1.43
100 91.1
96 ± 15
Alpacas
0 to 120 33.1
120 to 240 30.3
240 to 360 36.5
1.8e+002 ± 1.1e+002
Irrigated grass area
6 to 14 3.90
14 to 22 52.4
22 to 30 43.7
21.2 ± 5.1
Irrigation Efficiency
0.6 11.8
0.7 88.2
0.688 ± 0.032
Autonomy
Low 0
Enough 100
Agriculture Prod ($/year)
0 to 15000 1.29
15000 to 30... 71.6
30000 to 42... 27.1
2.6e+004 ± 7.6e+003
Vicunas to Cash ($/year)
0 to 1200 2.13
1200 to 2400 3.97
2400 to 3600 93.9
2.9e+003 ± 5.4e+002
Alpacas to Cash ($/year)
0 to 1500 32.8
1500 to 3000 30.7
3000 to 4550 36.5
2.3e+003 ± 1.3e+003
Fiber Vicuna Price ($/k)
Restricted 100
No restricted .032
308 ± 0.21
Total Milk Production ($/y...
0 to 14500 14.6
14500 to 29... 44.0
29000 to 43... 41.4
2.6e+004 ± 1.1e+004
Income
0 to 100 0
100 to 200 0
200 to 300 0
300 to 400 0
400 to 500 0
500 to 600 0
600 to 700 100
Total Benefits ($/year)
0 to 15000 0
15000 to 30... 0
30000 to 45... 0
45000 to 60... 0
60000 to 75... 54.7
75000 to 84... 45.3
7.29e+004 ± 7e+003
Total Production ($/year)
0 to 23500 0
23500 to 47... 0
47000 to 70... 47.0
70500 to 94... 53.0
7.1e+004 ± 1.4e+004
Livestock Prod ($/year)
0 to 13000 0.60
13000 to 26... 18.8
26000 to 39... 41.8
39000 to 52... 38.8
3.5e+004 ± 1e+004
MAXIMIZING OUTCOMES

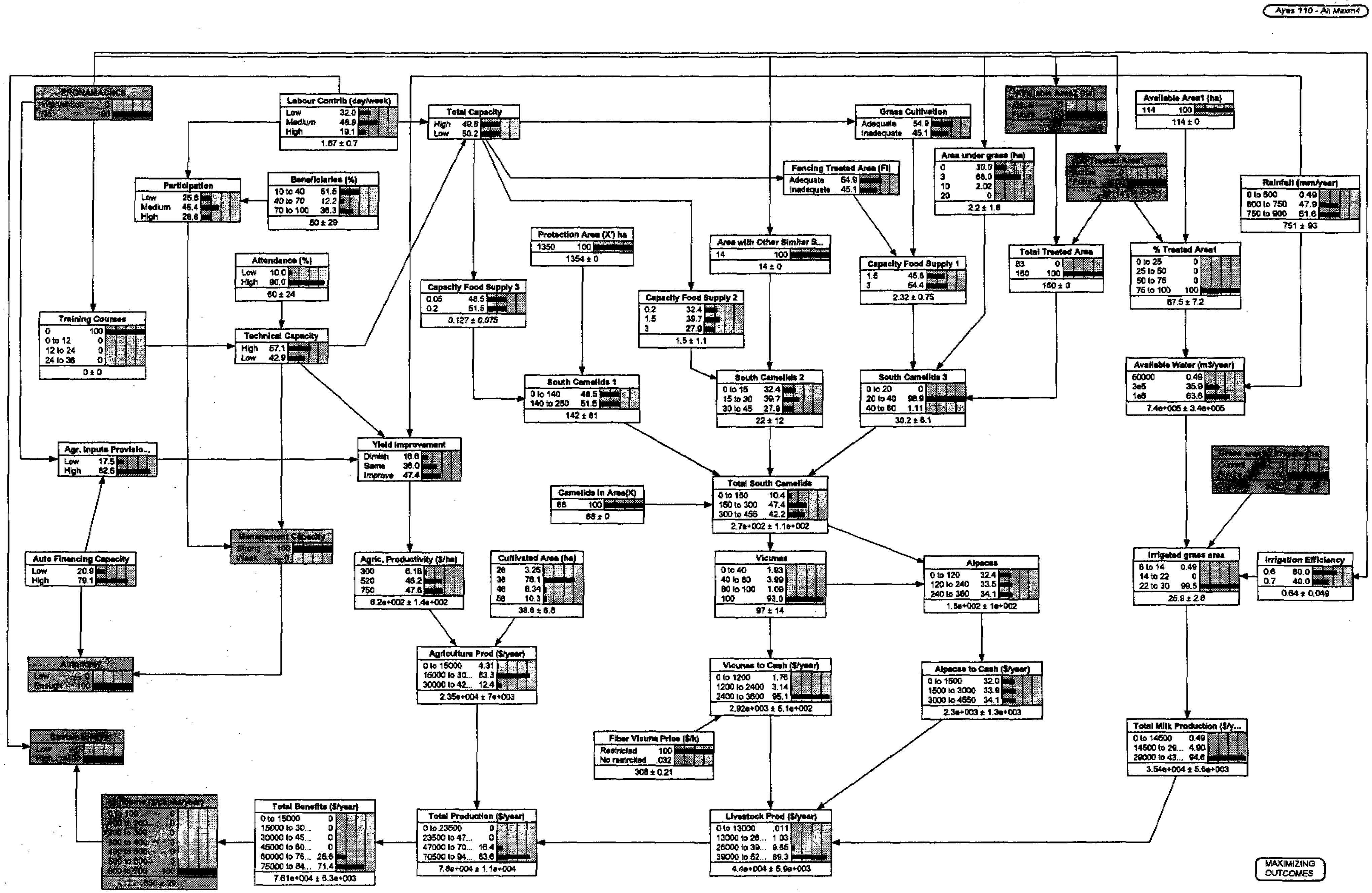
Ayas 110 - All Maxm2



MAXIMIZING OUTCOMES



Ayas 110 - All Maxm3
PRONAMACHCS
Intervention 96.3
No 3.69
Labour Contrib (day/week)
Low 41.2
Medium 42.3
High 16.5
1.75 ± 0.72
Total Capacity
High 66.7
Low 33.3
Grass Cultivation
Adequate 66.7
Inadequate 33.3
Available Area1 (ha)
114 100
114 ± 0
Area under grass (ha)
0 6.86
3 91.1
10 1.83
20 0.20
3 ± 1.4
Fencing Treated Area (FI)
Adequate 66.7
Inadequate 33.3
Rainfall (mm/year)
0 to 600 0.41
600 to 750 47.9
750 to 900 51.6
751 ± 92
Participation
Low 41.6
Medium 35.7
High 22.7
Beneficiaries (%)
10 to 40 58.1
40 to 70 11.1
70 to 100 30.7
47 ± 28
Protection Area (X') ha
1350 100
1354 ± 0
Area with Other Similar S...
14 100
14 ± 0
Attendance (%)
Low 5.24
High 94.8
82 ± 23
Capacity Food Supply 3
0.05 35.1
0.2 64.9
0.147 ± 0.072
Capacity Food Supply 2
0.2 23.2
1.6 43.0
3 33.9
1.7 ± 1.1
Capacity Food Supply 1
1.6 35.0
3 65.0
2.48 ± 0.72
Total Treated Area
83 0
160 100
160 ± 0
% Treated Area1
0 to 25 0
25 to 50 0
50 to 75 0
75 to 100 100
87.5 ± 7.2
Training Courses
0 3.69
0 to 12 60.8
12 to 24 22.2
24 to 36 13.4
11.6 ± 9.5
Technical Capacity
High 91.9
Low 8.06
South Camelids 1
0 to 140 35.1
140 to 280 64.9
161 ± 78
South Camelids 2
0 to 15 23.2
15 to 30 43.0
30 to 45 33.9
24 ± 12
South Camelids 3
0 to 20 0
20 to 40 98.6
40 to 60 1.40
30.3 ± 6.2
Available Water (m3/year)
50000 0.41
3e5 36.0
1e6 63.6
7.4e+005 ± 3.4e+005
Agr. Inputs Provisio...
Low 3.73
High 96.3
Yield Improvement
Dimish 5.20
Same 24.2
Improve 70.6
Camelids in Area(X)
68 100
68 ± 0
Total South Camelids
0 to 150 7.32
150 to 300 39.3
300 to 455 53.4
3e+002 ± 1.1e+002
Management Capacity
Strong 100
Weak 0
Auto Financing Capacity
Low 27.3
High 72.7
Agric. Productivity ($/ha)
300 2.48
520 33.1
750 64.5
6.6e+002 ± 1.2e+002
Cultivated Area (ha)
26 3.95
36 75.6
46 9.83
56 10.6
38.7 ± 7
Vicunas
0 to 40 1.36
40 to 60 2.81
60 to 100 0.77
100 95.1
98 ± 12
Alpacas
0 to 120 25.6
120 to 240 31.2
240 to 360 43.2
2e+002 ± 1e+002
Irrigated grass area
6 to 14 0.41
14 to 22 0
22 to 30 99.6
25.9 ± 2.5
Irrigation Efficiency
0.6 11.8
0.7 88.2
0.688 ± 0.032
Autonomy
Low 0
High 100
Agriculture Prod ($/year)
0 to 15000 1.81
15000 to 30... 81.5
30000 to 42... 16.7
2.45e+004 ± 6.9e+003
Vicunas to Cash ($/year)
0 to 1200 1.25
1200 to 2400 2.21
2400 to 3600 96.5
2.94e+003 ± 4.7e+002
Alpacas to Cash ($/year)
0 to 1500 25.3
1500 to 3000 31.5
3000 to 4550 43.2
2.5e+003 ± 1.3e+003
Fiber Vicuna Price ($/k)
Restricted 100
No restricted .032
308 ± 0.22
Total Milk Production ($/y...
0 to 14500 0.41
14500 to 29... 5.31
29000 to 43... 94.3
3.54e+004 ± 5.6e+003
Sustainability
Low 0
High 100
Income ($capita/year)
Total Benefits ($/year)
0 to 15000 0
15000 to 30... 0
30000 to 45... 0
45000 to 60... 0
60000 to 75... 26.0
75000 to 84... 74.0
7.84e+004 ± 6.1e+003
Total Production ($/year)
0 to 23500 0
23500 to 47... 0
47000 to 70... 13.4
70500 to 94... 86.6
7.9e+004 ± 1e+004
Livestock Prod ($/year)
0 to 13000 .007
13000 to 26... 0.84
26000 to 39... 10.1
39000 to 52... 89.0
4.39e+004 ± 5.9e+003
MAXIMIZING OUTCOMES



Ayas 110 - All Maxm4
Labour Contrib (day/week)
Low 32.0
Medium 48.9
High 19.1
1.87 ± 0.7
Total Capacity
High 49.8
Low 50.2
Grass Cultivation
Adequate 54.9
Inadequate 45.1
Available Area1 (ha)
114 100
114 ± 0
Participation
Low 25.8
Medium 45.4
High 28.8
Beneficiaries (%)
10 to 40 51.5
40 to 70 12.2
70 to 100 36.3
50 ± 29
Fencing Treated Area (FI)
Adequate 54.9
Inadequate 45.1
Area under grass (ha)
0 30.0
3 68.0
10 2.02
20 0
2.2 ± 1.8
Rainfall (mm/year)
0 to 600 0.49
600 to 750 47.9
750 to 900 51.6
751 ± 93
Protection Area (X') ha
1350 100
1354 ± 0
Area with Other Similar S...
14 100
14 ± 0
Attendance (%)
Low 10.0
High 90.0
60 ± 24
Capacity Food Supply 3
0.05 48.5
0.2 51.5
0.127 ± 0.075
Capacity Food Supply 2
0.2 32.4
1.5 39.7
3 27.9
1.5 ± 1.1
Capacity Food Supply 1
1.5 45.6
3 54.4
2.32 ± 0.75
Total Treated Area
83 0
160 100
160 ± 0
% Treated Area1
0 to 25 0
25 to 50 0
50 to 75 0
75 to 100 100
87.5 ± 7.2
Training Courses
0 100
0 to 12 0
12 to 24 0
24 to 36 0
0 ± 0
Technical Capacity
High 57.1
Low 42.9
South Camelids 1
0 to 140 48.5
140 to 280 51.5
142 ± 81
South Camelids 2
0 to 15 32.4
15 to 30 39.7
30 to 45 27.9
22 ± 12
South Camelids 3
0 to 20 0
20 to 40 98.9
40 to 60 1.11
30.2 ± 6.1
Available Water (m3/year)
60000 0.49
3e5 35.9
1e6 63.6
7.4e+005 ± 3.4e+005
Agr. Inputs Provisio...
Low 17.5
High 82.5
Yield Improvement
Diminish 16.6
Same 36.0
Improve 47.4
Camelids in Area(X)
88 100
88 ± 0
Total South Camelids
0 to 150 10.4
150 to 300 47.4
300 to 450 42.2
2.7e+002 ± 1.1e+002
Management Capacity
Strong 100
Weak 0
Auto Financing Capacity
Low 20.9
High 79.1
Agric. Productivity ($/ha)
300 6.18
520 46.2
750 47.6
6.2e+002 ± 1.4e+002
Cultivated Area (ha)
28 3.25
38 78.1
48 8.34
58 10.3
38.6 ± 6.8
Vicunas
0 to 40 1.93
40 to 80 3.99
80 to 100 1.09
100 93.0
97 ± 14
Alpacas
0 to 120 32.4
120 to 240 33.5
240 to 360 34.1
1.8e+002 ± 1e+002
Irrigated grass area
8 to 14 0.49
14 to 22 0
22 to 30 99.5
25.9 ± 2.8
Irrigation Efficiency
0.6 60.0
0.7 40.0
0.64 ± 0.049
Autonomy
Low 0
Enough 100
Agriculture Prod ($/year)
0 to 15000 4.31
15000 to 30... 83.3
30000 to 42... 12.4
2.35e+004 ± 7e+003
Vicunas to Cash ($/year)
0 to 1200 1.76
1200 to 2400 3.14
2400 to 3600 95.1
2.92e+003 ± 5.1e+002
Alpacas to Cash ($/year)
0 to 1500 32.0
1500 to 3000 33.9
3000 to 4550 34.1
2.3e+003 ± 1.3e+003
Fiber Vicuna Price ($/k)
Restricted 100
No restricted .032
308 ± 0.21
Total Milk Production ($/y...
0 to 14500 0.49
14500 to 29... 4.90
29000 to 43... 94.6
3.54e+004 ± 5.6e+003
Total Benefits ($/year)
0 to 15000 0
15000 to 30... 0
30000 to 45... 0
45000 to 60... 0
60000 to 75... 28.6
75000 to 84... 71.4
7.61e+004 ± 6.3e+003
Total Production ($/year)
0 to 23500 0
23500 to 47... 0
47000 to 70... 16.4
70500 to 94... 83.6
7.8e+004 ± 1.1e+004
Livestock Prod ($/year)
0 to 13000 .011
13000 to 26... 1.03
26000 to 39... 9.65
39000 to 52... 89.3
4.4e+004 ± 5.9e+003
MAXIMIZING OUTCOMES