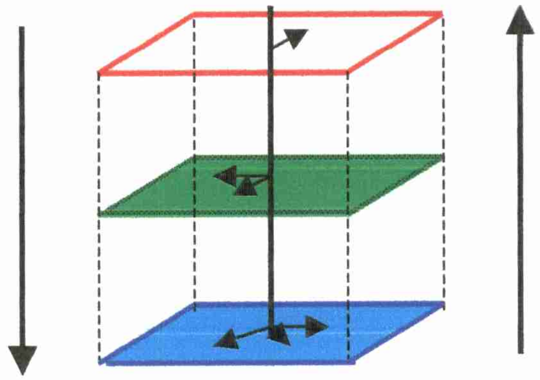
Desert Margins Program (DMP)

Optimizing resource use at village and district levels in the Desert Margins of West Africa (ORU)



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ICRISAT, Niamey, Niger, 8 - 19 June 1998

N. van Duivenbooden & T. Wyatt, editors

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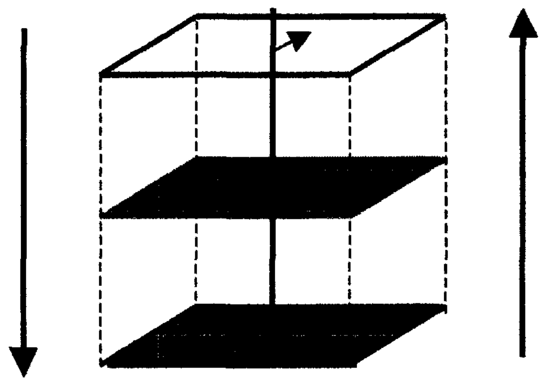

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Abstract

Proceedings of an international workshop, held on the use of programming models in the analysis of resource use and decision support systems in West Africa, are presented. An important theme is the linking of various levels of aggregation to better identify constraints and effective development strategies. Goals of various stakeholders at the household, village, and district levels are examined and examples are discussed to demonstrate how the goals might be translated into objectives for a programming model. Possible strategies or policy interventions are also examined to suggest how scenarios are developed to evaluate the efficiency of these interventions. The use of ethno-classifications of soil, in order to make recommendations more relevant to the land user, is also discussed. This document is part of a serie on progress in developing a multi-scale methodology and a decision support system.

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1. *Introduction*

1.1 Framework

The International training workshop 'Using multiple-goal programming models to optimize resource use in semi-arid regions' is part of the project 'Optimizing resource use at village and district levels in the Desert Margins of West Africa (ORU)' in the framework of the Desert Margins Program (DMP). The DMP/ORU project is a collaborative research effort between the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) and the national agricultural research systems (NARS) of Burkina Faso, Mali and Niger to improve the use of natural, human and financial resources in the Sahelian zone. The project works at the level of the household, the village, and the district. The major purpose of the workshop was to familiarize project collaborators on the use of bio-economic models to be used as part of a multi-scale decision support system (MDSS). The workshop was hosted by ICRISAT at its Sahelian Center in Niamey, Niger, from 8 to 19 June, 1998.

The workshop was initially planned for the dry period of 1997 and for a period of three weeks. Because of delays in filling the position of an agricultural economist, the workshop had to be postponed. Given the time constraints, including the onset of the rainy season, it was decided to hold instead a two-week workshop that included a course on the principles of linear and non-linear programming, a presentation of progress reports for the project, and the use of a Global Positioning System (GPS). Dr. Bruno Barbier, Research Fellow at the International Food Policy Research Institute (IFPRI), was the principal trainer for the programming course and Fabriz Lheriteau and Bruno Gerard, both of ICRISAT, provided the introduction to GPS.

Participants from two other projects, 'Exploiting multi-scale variability of land use systems to improve natural resource management in the Sudano-Sahelian Zone of West Africa (MUSCLUS)' and a DMP project funded by the International Development Research Center (DMP/IDRC), which also are working to develop decision support systems, were invited in order to increase interaction between the projects and to foster institutional collaboration. The MUSCLUS project is the parent project of DMP/ORU and focuses on the Sudan-Savanna zone of Burkina Faso, Mali and Niger. The DMP/IDRC project is conducted in Botswana, Burkina Faso and Kenya.

As a follow up activity to this workshop and to cover topics originally planned for the workshop, Drs. N. van Duivenbooden and T. Wyatt will visit the National Agricultural Research Systems (NARS) in Burkina Faso, Mali and Niger during the first half of September. In November, Dr. T. Wyatt will visit the Sahel stations of the same National Agricultural Research System to provide further support in the development and use of the multi-scale decision support systems.

In these proceedings, we focus upon the concepts and methodologies that are used in the projects, rather than providing a report of the programming course or of the presentations. The latter will be available, in detail, in other reports.

1.2 Goal and objectives

The primary goal of the workshop was to provide participants with the essentials of linear and non-linear programming for use in assisting resource management decisions at different levels of scale. Secondary goals were to present progress reports and to plan further research. In addition, the principles of the functioning of a GPS were taught.

The specific objectives of the workshop include:

- Participants obtain a basic knowledge of the Generalized Algebraic Modeling Systems (GAMS) software and are able to write and interpret simple linear and non-linear programming models;
- Participants contribute to the linking of different levels of scales which can ultimately be incorporated in a Multi-scale Decision Support System (MDSS);
- Identification of stakeholders' goals at different levels of scale;
- Exchange of ideas and results of different projects (DMP/ORU, MUSCLUS, DMP/IDRC);
- Participants have basic knowledge of the functioning of a GPS.

2. *Progress of projects*

The progress of each DMP/ORU, MUSCLUS, and DMP/IDRC project in each country was presented, and the following observations were made:

1. The DMP/ORU and MUSCLUS projects are well advancing, and the multi-scale characterization is almost finalized in Burkina Faso and Mali, but not yet in Niger. The back-log in progress in the latter country was questioned, and the project leader will increase efforts to regain the schedule. Dr. N. van Duivenbooden and T. Wyatt will make an analysis of the characterizations, after reception of the reports in July. This analysis will then help in identifying gaps in data for each location. This will be discussed with the teams while they visit the various West African locations in September.
2. In contrast to biophysical and social characterization, the policy environment and economic aspects have not yet been described to a sufficient level. In combination with the goals set (see 3.1), it was recommended that the teams visit the various governmental organizations with a stake in the concerning village and district.
3. The multi-scale characterization of production systems as carried out for Niger, and mapping to the lowest geo-referenced administrative unit ('canton') will be used in the discussion to harmonize the production systems in the other countries.
4. In contrast to description of agricultural activities, the non-agricultural sector (important for off-season employment and income) was not described sufficiently by the various teams.

5. Soil classification will be done to the most detailed level possible, implying that different classifications have to be used; i.e., FAO at reconnaissance level, the French classification system at the district and village levels, and ethno-classifications of soils at the village and household levels. Some details may be lost when using this soil classification system at the village level, but this was justified as the decision support tools must be relevant to the land user.
6. In Mali, beginning November 1998, a new administrative unit will be introduced, the 'commune,' which is a combination of 5 to 10 villages. The commune is a basic collective territory of the new administrative decentralized and democratic organization of Mali. For the projects in Mali, this commune will thus replace the 'arrondissement'.
7. The DMP/IDRC project has only recently begun in Burkina Faso and Kenya (March 1998), and is about to start in Botswana. In Kenya and Burkina Faso the research sites have been identified. It was noted that activities are out of phase with the agricultural calendar due to delays in disbursement and reception of funds. The participants expressed their interest in the modeling techniques and it was discussed how the approach could help direct data collection.

3. *Outcome of working groups*

Several working groups were organized to discuss in greater detail certain key points. A major theme was the identification of the goals that various groups and decision-makers would like to realize at the different levels of aggregation. Later working groups discussed how these goals could be translated into objectives for the bio-economic models, particularly policy goals which are often not quantifiable, and how policies and/or development strategies could be modeled. Other groups discussed how to relate ethno-classification of soils to the scientific systems and how to link the different levels of analysis.

3.1 Goals of stakeholders

Before building a MDSS or a bio-economic model relating different levels of scales, the goals of the stakeholders at household, village, and district level should be known. The goals or objectives must be understood in order to develop a model that will help to analyze and evaluate strategies for achieving the objectives. Some of these goals were identified and, to a certain extent, refined (Table 1). Work remains to be done in further identifying other goals and strategies.

At the level of the district the overall goal is 'improvement of living conditions' (or 'rural development'), but as this has different aspects, the specific goals are given in Table 1. This goal is more or less the same as identified at the national level. Others at the national level include 'food security', 'balance of interest groups', 'environmental protection', and 'development'. These goals are set by politicians, often using general terms, while the people who have to execute the policies needs more quantitative than qualitative information.

The most important goal is to meet the demand for food while the other goals are not ranked. In addition, it was noted that constraints exist to prevent attaining certain goals at each scale level. These include, for instance, at the household level: cash, labor, drought, markets, and land tenure system; at the village level: availability of land, markets, and institutional framework; and at the district level: budget, land availability, political institutions, and infrastructure (Table 2). In some cases, in order to attain a goal, action is required at a different level, whether higher or lower. Note that these goals can not be used immediately in a programming model, some translation is required (see Section 3.2).

Table 1. Tentative goals of various stakeholders at three levels of scale.

GOAL		LEVEL		
		household	village	district
1	Meeting food demands	———	———	———
2	Increased revenues	———		
3	Social status	———		
4	Production and revenue security	———	———	
5	Construction of infrastructure		———	———
6	Improved natural resource management			
	a) Sustainable use of wood		———	———
	b) Sustainable exploitation of fishery		———	———
	c) Improved use of by-products			———
	d) Maintained and improved soil fertility	———	———	———
	e) Reduced erosion		———	
	f) Increased fodder production		———	———
7	Environmental / biodiversity protection		———	———
8	Avoidance of conflicts		———	———
9	Increased milk and meat production			———
10	Organization of socio-economic groups			———
11	Reduction of labor exodus			———

Elaboration of Table 1:

1. *Meeting food demands.* Some believe that this implies being self-sufficient, but food demand can also be met through the market, providing that an adequate distribution system exists. For rural areas, ensuring food security implies an increase in agricultural production, whether for home consumption or for sale in order to provide income. An increase of 4% is often mentioned, but in practice this value has to be set for each country and region; this need thus to be discussed with the various stakeholders in the coming months.

2. *Increased revenues.* An increase of 10% is considered already a large step (c.f. World

Bank), so that in practice this value has to be set for each country and region; this needs to be discussed with the various stakeholders in the coming months.

3. *Social status.* This is largely a cultural issue, but may be determined by the level of investments (equipment or in livestock) or of consumption goods and can thus be considered a subset of increased incomes.

4. *Production and revenue security.* That is, the avoidance of risk. Risk in agriculture is due both to the weather (production risk) and the market (price risk) and the two require different management strategies.

5. *Construction of infrastructure.* Building or improving facilities (education, health, roads, water points, dams, etc.) is often expressed as a goal, but it is also a means to improve access to resources.

6. *Improved natural resource management.* As a goal this is so large and so vague that it needs to be defined in terms of different and specific parameters:

   a) Sustainable use of wood implies the efficient use of wood at the household and village levels and the regeneration of forests at the village and district levels;

   b) Sustainable exploitation of fish refers to the efficient use of aquatic resources to provide an alternative and stable source of meat proteins and income.

   c) Improved use agricultural by-products (cottonseed cake, crop residue, etc.). Constraints include their cost and availability (distribution of processed products).

   d) Maintained and improved soil fertility includes the efficient use of locally available resources such as rock phosphate and organic matter (farmyard manure, compost and crop residues) as well as well-timed distribution of imported chemical fertilizers.

   e) Reduced wind and water erosion, one important aspect of maintaining soil fertility, requires cost effective technologies which may include hedge rows, mulches and stone bunds.

   f) Increased fodder production is a means of protecting common lands and increasing the supply of livestock products for consumption and revenue. It may be achieved by the cultivation of fodder or multi-purpose crops, such as cotton for cotton seed meal as in Mali.

7. *Environmental / biodiversity protection.* The former includes protection of forest and pastures while the latter refers to natural flora and fauna as well as to crop species and varieties.

8. *Avoidance of conflicts.* This refers to social conflicts, e.g., between ethnic groups, between social or economic groups, and between farmers at the village level in respect of land allocation. Conflicts occur also at household level (land tenure), but avoiding conflicts cannot be seen as a priority goal of the household.

9. *Increased milk and meat production.* The goal is to improve nutrition and also to increase

farmers' income. It may require improved genetic resources, development of fodder banks, and improved availability of agricultural by-products.

10. *Organization of socio-economic groups.* This is seen as a means to facilitate rural development.
11. *Reduction of labor exodus.* As a goal, reducing migration needs further examination in the future through discussions with various stakeholders at the three levels of scale. In Burkina Faso, projects exist to try to keep young people in the region. However, at the household level the goal of increasing income (and meeting food demand) implies or even requires (as in some parts of Niger) that households engage in temporary of permanent migration. There is thus a conflict between different stakeholders (i.e. at different levels of scale).

Table 2. Selected constraints at different levels of scale.

Constraint	District	Village	Household
Political institutions	—		
Budget	—	—	—
Land (availability and quality)	—	—	—
Infrastructure (roads, etc.)	—	—	—
Extension		—	
Market access / price risk		—	—
Land tenure system		—	—
Timing of farm activities			—
Labor (availability and price)			—
Inputs (availability and price)			—
Rainfall (quantity, distribution)			—
Education			—

3.2 Translation of stakeholder goals into model goals

3.2.1 General

Goals are set by stakeholders (farmers, policy makers, communities, etc.) and these are referred to as 'stakeholder-goals'. Often these goals are qualitative in nature, dealing with 'improvements' or 'increases,' and without reference to the level or scale. For a decision support system, however, these goals need to be translated into quantifiable objectives, referred to as 'model-goals'. A model-goal is a function, i.e. something to maximize (e.g. profit, consumption) or minimize (e.g., risk). The result is a single value (a scalar) that measures the total contribution (to profit or risk) of all the activities in the model. Optimizing (maximizing or minimizing) this goal subject to the constraints placed on the system, will result in suggested activities or interventions that then need to be translated back into language understandable to the stakeholders. Figure 1 shows the flow chart how to define and redefine goals.

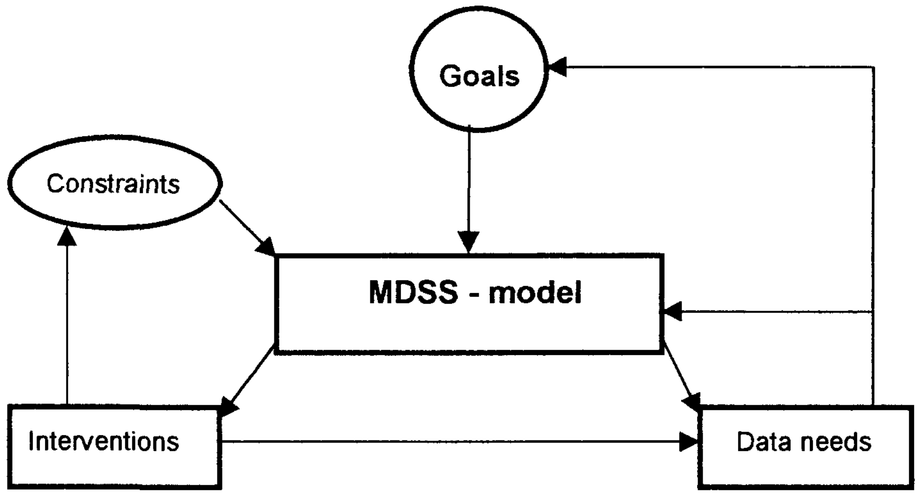

Figure 1. Flow chart of defining goals and constraints in building the decision support system.

The goals (or objectives) and the constraints on the system at a given level of scale form the basis of the model. Constraints limit possible activities and achievements. There are, for instance, resource limits (e.g., land), process limits (e.g., yields as functions of physical characteristics and inputs), and activity limits (e.g., institutional factors). Processes are links between activities. They can refer to consequences (e.g., land degradation) or they can describe feed-backs (e.g., land use practices may cause degradation which in turn reduces crop yield and influences land use practices).

Interventions or policies are changes to the systems that try to alleviate the constraints. They may be suggested by the model or planned in advance. Many of these interventions will be expressed by policy-makers as goals: such as improved health care or improved varieties. The impact of these interventions can be explored through different scenarios. These scenarios test the efficiency and acceptability of the interventions. In a MDSS model, goals, constraints, and processes will appear in the form of equations. Quantifying these relationships (equations) determine the data needs to make the model operational and data availability will often determine what goals can be examined and the reliability of the results.

Given the available time it was not possible to translate all identified stakeholder-goals into model-goals. Two goals suggested by the participants were briefly examined.

3.2.2 Maximize food production

The general stakeholder-goal of 'to improve natural resource management' can be made more precise and quantifiable as the model-goal 'to maximize food production' (or 'to minimize food shortage')[1]. A basic start would be to define the following equations:

yield (crop)	=	function (soil moisture, soil fertility, practices, inputs, labor)
livestock (species)	=	function (forage production, inputs, labor)
forage	=	function (rainfall, soil fertility, number of livestock)
soil moisture	=	function (rainfall, soil type, practices)
soil fertility	=	function (erosion rate, soil type, practices)
erosion	=	function (crop type, soil type, practices)
practices	=	land use practices such as fallow, irrigation, erosion control, fertilization, etc.

These equations must be quantified; the impact of land use practices must be measured, for example. These equations pertain to the level of the household, but some require more specific detail. That is, for each *field* of soil type, s:

Erosion(s)	=	R * K(s) * L(s) * S(s) * C(s) * P(s) (Universal Soil Loss Equation)
SOILF(s,t)	=	SOILF(s, t-1) + function(fertilizer use(s, t-1), erosion(s, t-1), crop cultivated(s, t-1))

where,

R	=	Rainfall erosivity
K(s)	=	Erodibility, depending on soil type
L(s)	=	Length of field
S(s)	=	Slope of field
C(s)	=	Crop coverage depending on crop species
P(s)	=	erosion control practices (terraces, mulching, living hedges)
SOILF(s, t)	=	soil fertility at time t

Note that high levels of production may cause high rates of erosion. Another goal can be added as a constraint to ensure that erosion does not exceed acceptable levels:

Erosion (s) $\leq$ tolerance level

At the *household* level we define total production (the objective function) as well as household constraints:

PROD-H	=	Σ_s yield(s) * area (s)
LAND-H	$\geq$	Σ_s area(s)
LABOR-H	$\geq$	Σ_s Lcrop(s) + Lwage + Lmig - Lhired
EQUIP-H	$\geq$	Σ_s equipment(s)

where,

LAND-H	=	land available to the household, which cannot be exceeded by area cultivated
LABOR-H	=	total available labor, which can be allocated to crop production, wage labor or migration activities and can be augmented by hired labor
EQUIP-H	=	total available equipment, which cannot be exceed by cultivation requirements

[1] We do not specify which stakeholder set this goal, but it is clearly not the farmer who must also be concerned with non-food needs such as clothing, shelter, education of children, etc. and who will therefore not put all of his or her efforts and resources into food production. Also note that 'maximizing food production' is not the same as 'minimizing food shortage' since the former implies achieving the greatest possible production regardless of cost or actual need whereas the latter implies some level of need that we wish to meet.

Given the objective, the processes and the constraints, we could use the model to determine the activities (crops, practices, etc.) that would give us the greatest possible production.

If we want to maximize production at the next higher level of scale, i.e., a *village* with different types of households (h), the following could be used:

$$\text{PROD-V} = \Sigma_h \text{PROD-H(h)}$$
$$\Sigma_h \text{Lwage(h)} = \Sigma_h \text{Lhired(h)}$$

All household equations apply and, in addition, there is the constraint that the wage labor supplied by village households must be hired by other village households (under the assumption that there is no exchange of labor between villages). A solution to this model would suggest ways of allocating labor between households in order to maximize production at the village level. A model could also help to determine the best allocation among the households of village communal lands.

In the case where markets exist between villages, especially in labor, we would define the following equations at the next highest level, the *district*:

$$\text{PROD-D} = \Sigma_v \text{PROD-V(v)}$$
$$\Sigma_v \Sigma_h \text{Lwage(h)} = \Sigma_v \Sigma_h \text{Lhired(h)}$$

Thus, patterns of resource movements within a zone can be modeled.

3.2.3 Avoiding conflicts

The next example taken by the group was the stakeholder-goal 'to avoid conflicts'. To be able to define a model-goal it is important to identify first who have conflicts and why. Conflicts exist, for example, between herders and agriculturists, between agriculturists and between agriculture and wildlife. Availability and distribution of resources (that is, defining who has access to or control of the resources) can thus be key issues. The example below examines conflict between herders and agriculturists.

At the *village* level the model goal is to maximize total village income, INC-V, that is, to maximize total net benefits:

$$\text{INC-V} = \Sigma_h \text{return(c)} * \text{PROD(c,h)} + \text{return(l)} * \text{PROD(l,h)}$$
$$\text{PROD(c,h)} = \text{yield(c)} * \text{area(c,h)}$$
$$\text{PROD(l,h)} = \text{yield(l)} * \text{area(l,h)}$$
$$\text{LAND-V} = \Sigma_h \text{area(c,h)} + \text{area(l,h)}$$

where,

return	=	the net returns from crop (c) or livestock (l) production
PROD(c,h)	=	production of agriculturist household
PROD(l,h)	=	production of herder household
LAND-V	=	total village land

Note that total production, not just the marketed surplus, contributes to household income since the value of home consumption should be included in the household's net benefits.

The goal of reducing conflicts can be included in the model in various ways, depending on the source of the conflict or the village's perception of equity. Some possibilities were suggested:

A) An equal distribution of land between agriculture and livestock activities

$$\Sigma_h \text{area}(c,h) \quad = \quad \Sigma_h \text{area}(l,h)$$

B) A distribution of income, where the income from livestock activities is some weighted factor of agricultural activities, where w is the weight. An equal distribution between activities would mean that $w = 1$. An equal distribution between groups would mean that w = number of herder households divided by the number of agricultural households.

$$\Sigma_h \text{return}(c) * \text{PROD}(c,h) \quad = \quad w * \Sigma_h \text{return}(l) * \text{PROD}(l,h)$$

C) A minimum acceptable level of production for all households, perhaps given minimum subsistence requirements or minimum income levels.

$$\text{PROD}(*,h) \quad \geq \quad \text{PMIN}(*)$$

Note that the above equations are not worked out in full detail, and that more equations can be defined (depending on level of detail needed, data availability, etc.). The group noted that conflicts will always exist because they do not necessarily originate from the allocation of land.

From these examples it is concluded that the translation of policy goals into the model is an extremely important step in the development of the decision support system and must always bear in mind the objectives of the actual resource user.

3.3 Goals, interventions, and data requirements

3.3.1 General

Following the work on translating goals, the group took up the question of how to incorporate political policies or strategies into the models, that is, how to develop scenarios for evaluating the impact of interventions. The group took as an example the overall policy goal of insuring food security or increasing food production. They then suggested potential policy interventions available to governments at the national, district, and village levels and discussed how these interventions would be described in the model. The purpose of these models is to examine alternative policies for their effects on decisions of the land user, whether a farmer or herder or agro-pastoralist. A brief discussion of data requirements followed although it was felt that a well-described constraint or scenario provides a clear explanation of the needed data.

Possible interventions that could be undertaken at the national level include price subsidies, for either inputs or outputs, and research and extension programs. At the district or village level, policies or strategies include improving infrastructure (for example, roads, health service, storage, education, etc.) and credit programs.

At the *household* level, we begin with the assumption that farmers are trying to maximize the returns, or profit, they receive from production of crops and/or livestock, that is, the difference between the value of the output (whether for sale or home consumption) and the total cost of the inputs. This provides producers with the maximum benefits that can be used to purchase non-food necessities, food that the household cannot produce itself and other goods as well as to make investments in future production. Therefore,

$$\text{profit} = \Sigma_c\, P(c) * PROD(c) + \Sigma_l\, P(l) * PROD(l) - \Sigma_i\, P(i) * Q(i)$$

where,

P	=	price of the commodity (crop, c; livestock, l) or input, i
PROD(c)	=	production of crop, c
PROD(e)	=	production of livestock product, l
Q(i)	=	quantity of purchased input, i

The constraints faced by the household are those that were discussed previously (Section 3.2) so the group concentrated on parameters or constraints that would be changed to represent policy interventions, in this case, subsidies, improvements in infrastructure, credit, and research and extension.

3.3.2 Subsidies

In the case of input subsidies, it is noted that the price faced by the farmer, P(i), is lower than the true market price, Pmarket(i) by the amount of the subsidy. Similarly, output subsidies would increase the price received by the farmer.

$$P(i) = Pmarket(i) - subsidy(i)$$
$$P(c) = Pmarket(c) + subsidy(c)$$

Compared to the baseline scenario, the impact of the subsidy or subsidies on production could be examined. In addition, consequences of these policies on soil fertility or other factors of interest, because of their impacts on input use and crop choice, can be explored. At the district or national level, however, it would be important to see the impact of such subsidies on the budget, thus it would be desirable to aggregate upwards to determine the total demand for the subsidized input and/or the total supply of the subsidized output and, therefore, the total expenditure required by the government. Contacts with government and non-governmental organizations are thus crucial to obtain information on their goals and strategies.

3.3.3 Infrastructures: Roads

The impact of changes in infrastructure, such as improvements in roads, on agricultural production can be seen through their effects on the price of goods in the market. Road improvements may reduce the cost of transporting goods, either by reducing the costs to transporters (e.g., maintenance of vehicles) or by increasing competition between transporters. This has the effect of increasing the price received by producers and/or decreasing the price of imported inputs such as fertilizer.

One way of modeling this situation would be to consider prices in the base scenario as:

P(i)	=	Pworld(i) + transport(i)
P(c)	=	Pworld(c) - transport(c)

where,

Pworld	=	the price of the good in the world or principal market
transport(*)	=	per unit cost of transport

In the development scenario, road improvements would result in a decrease in transport(*) and the impact of cheaper inputs or higher output prices could be determined by comparing the results to the base scenario.

Another possibility is to recognize that some isolated villages face a constraint on the amount of output they can sell because only a few trucks come to the village to collect produce. This could be represented by a constraint on marketed surplus:

MS(c)	=	trucks(road) * q(c)

where,

MS(c)	=	marketed surplus (PROD(c) - home consumption)
trucks(road)	=	number of trucks that come to the village as a function of road conditions
q(c)	=	quantity of the product that can be hauled by a truck

Road improvements result in more trucks coming to the village and permitting more sales. The consequences of improved access may include expanded (more land) or intensified (more inputs) production of cash crops and/or a shift in cultivation toward marketable commodities. As above, models could explore the consequences of these changes on land degradation, adoption of new technologies and other factors of interest.

In the coming months, contacts with ministries, traders, etc. will provide an indication if this issue is of interest and if the data necessary to construct the models is available.

3.3.4 Infrastructure: medical facilities

In Burkina Faso, for example, labor availability is limited by occurrence of malaria, especially during the weeding period. Improved health care (access to medical facilities) could therefore have an impact on agricultural production by reducing the number of days a person is too sick to work in the fields. This intervention addresses the labor constraint faced by the *household*. The constraint on labor can be modeled as

LABOR-H	=	POP(h) * DAYS(health)

where,

LABOR-H	=	labor that the farm has to allocate to various activities (crop production, livestock production and other off-farm activities)
POP(h)	=	number of workers in the household
DAYS	=	number of days a person can work as a function of their health or the presence of medical facilities.

Necessary data would include the prevalence and impact of diseases and the potential effectiveness of new or additional medical facilities in preventing or treating disease. Certain NGOs, including CARE International which has projects in the Bankass region of Mali, could potentially have data.

3.3.5 Credit

The impact of a credit program can be observed by relaxing the cash constraint faced by the farmer. If the farmer must pay for all purchased inputs from cash available then he faces the constraint that

$$P(i) * Q(i) = K$$

where,
K = capital available to the farmer.

The alternative scenario would observe the impact on production of allowing the farmer to have credit such that

$$P(i) * Q(i) = K + credit$$
$$profit = \Sigma_c P(c)*PROD(c) + \Sigma_l P(l)*PROD(l) - \Sigma_i P(i)*Q(i) - r*credit$$

where,
credit = amount borrowed
r = interest rate

The decision maker could then use a model to predict to what extent a credit system would increase production and whether it would increase production of food or of cash crops. Again, discussions with governmental and non-governmental organizations are crucial in obtaining data on their strategies and their impacts.

3.3.6 Research and extension

Finally, the group examined the effect of research and extension. If production in the base scenario can be described as

$$PROD(c) = YIELD(c) * AREA(c)$$

where,
YIELD(c) = yield of produce c (kg ha^{-1})
AREA(c) = area cultivated with crop c (ha)

Research and development of new varieties or extension of new varieties may permit the producer to increase yields, using the same inputs. Thus, in the new scenario

$$YIELD1(c) = YIELD(c) + delta(c)*YIELD(c)$$

where,
delta(c) = increase in yields as a percent of previous yields

Alternatively, the new variety, with its characteristics for higher yield or better drought tolerance, could be introduced as a different crop, and its acceptability into the cropping system could be examined.

The group stressed that these interventions were discussed in the context of increasing food security, where scenarios would measure the increase in production and would help national, district, or village leaders decide if the policies were useful in meeting their goals. However, many of these interventions could have impacts on other goals of these leaders including increasing rural incomes, rural development and reducing rural exodus. Data for these scenarios must be collected but it was believed that most of the necessary data would be available from research and other institutes. Given these examples, participants felt well prepared to meet with other institutions to discuss goals and data availability.

3.4 Ethno-classification of soils

The ethno-classification of soils is an important tool in the communication between researchers and farmers at the village and household level. In the framework of the projects it will help us in to link research (based on chemical analyses and scientific comparisons) with practical recommendations. In Mali, considerable experience has been gained in this area. The classification system has two levels, the highest one (level 1) based on the geomorphology (plateau, slope, valley bottoms, etc.). The second level based on type of soil with 6 criteria (in order of importance for farmers): (*i*) soil depth, (*ii*) stoniness (presence of large stones), (*iii*) hydromorphy, (*iv*) texture of surface layers (related to labor input for ploughing, etc.), (*v*) erosion and level of degradation, and (*vi*) color of soil surface (related to soil fertility). The discussion revealed the following for the three levels of scale:

Household: use of the complete ethno-classification of soils. Degradation should be taken into account, and preferably built in models to examine the costs and benefits of restoring soil fertility, stopping desertification, etc.

Village: classification used for planning and management of the village grounds based on the highest level of the ethno-classification together with soil texture, soil depth, and severity of degradation (in terms of surface, and amount of soil lost through wind and water erosion).

District: need for a translation of ethno-classification level 1 into FAO or French classification.

For the projects this implies (and partly reconfirms) the following activities. At the village level, to create soil and land use maps at 1:25,000. At the household level, to create a detailed soil map for the whole village on the basis of selected samplings on soil organic manure, texture of surface layer, crop yield (for different soil types and species), and severity of degradation (e.g. in terms of % of area with crusts).

It is noted that all relevant degradation parameters that can be included in a bio-economic model are not identified, this needs to be done in the future in collaboration with other DMP partners (e.g. ORSTOM).

3.5 Linking levels of scales

Scales are linked through different parameters and at each level of scale a range of decisions have to taken by stakeholders (Table 3). The decisions (type of culture, type and quantity of inputs, land allocation strategy for different crops, etc.) at one level determine processes and constraints at another level (Figure 2).

Table 3. Important parameters to be included in the model, and the decisions to be made by stakeholders.

SCALE	PARAMETER	DECISION TO BE MADE	STAKEHOLDER
Household	Yield	Varieties to be used	Farmer
	Labor	Allocation of labor for number of activities	
	Land area	Allocation of land to number of activities	
	Income	Strategy to maximize income	
	Equipment	Acquisition and efficient use of equipment	
	Inputs	Type and quantity of inputs	
	Crops	Type and area allocated	
	Livestock	Type, number, and area of pasture	
	Soil type	Crop, equipment, inputs, practices	
Village	Production	Quantity and trade	Village chief
	Labor	Cost of labor	Land chief
	Income	Maximize income	Land priest
	Land area	Allocation of land	Farmers association
	Land tenure	Buy, rent, own	Credit institutions
	Credit	Cooperations; agro-banks	(NGO's, etc.)
District	Production	Quantity	District authority
	Labor	Migration	Working group of
	Land tenure	Laws / conflicts	cooperations
	Credit	Rules (rates, installments)	Private industries
	NRM	Laws to allocate land for specific needs	Extension service
	Income	Tax rate	

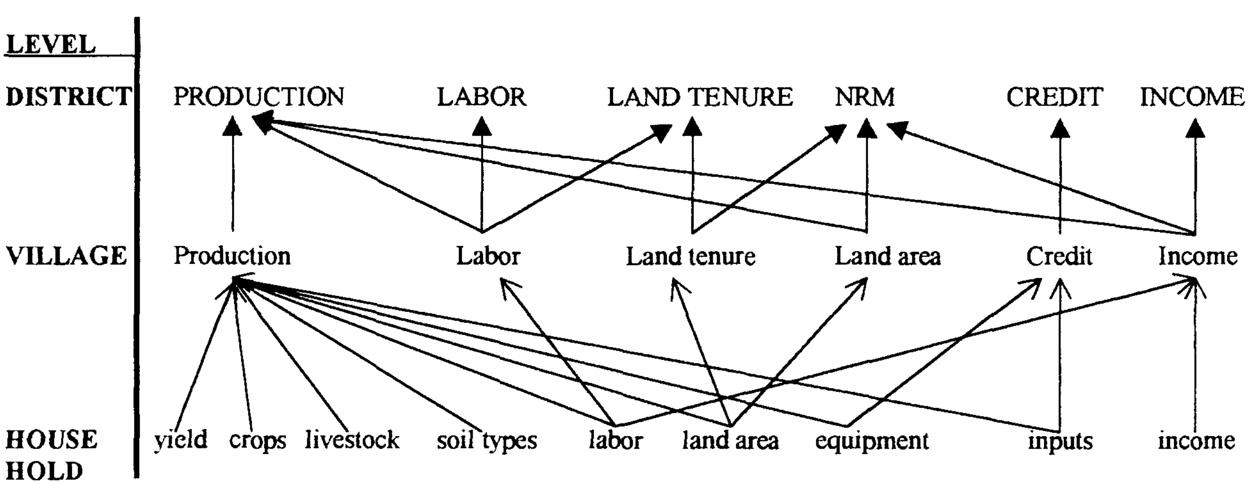

Figure 2. Hierarchical structure of influences of key parameters in de decision support system. NRM = Natural resource management (built upwards only).

The scale of the model and the degree of aggregation will be determined by the question or issue that is to be examined. Results of analyses at one level of scale may help to identify constraints at a different level or predict where problems caused by policies at one level may arise.

3.6 Collaboration between DMP/ORU, DMP/IDRC, and MUSCLUS projects

In this workgroup the goals were to explore possibilities of collaboration between the DMP/ORU and MUSCLUS projects and the DMP/IDRC project, and to discuss collaboration/networking among the DMP participating countries. Relevant to the collaboration with DMP/ORU and MUSCLUS projects are the last two objectives of the whole DMP:

- Developing and fostering improved and integrated management technologies and policies to achieve greater productivity in the desert margins.
- Constructing and testing levels and elements in decision making in the adoption of improved resource management policies.

It was felt that the expertise developed by the DMP/ORU and MUSCLUS projects could be helpful in:

1) Simulating the impact of the improved management technologies;
2) Facilitating the integration of different management technologies;
3) Helping to create linkages between the various levels of decision making for achievement of stakeholder goals.

DMP/IDRC could in its turn collect relevant data for the DMP/ORU and MUSCLUS projects for an eventual comparison of and extension to other DMP sites.

With respect to the collaboration or networking among the DMP countries, the following is noted:

1) The need for reciprocal communication to facilitate sharing of ideas and to keep each other updated on the progress respective countries/scientists are making, through Email, for example;
2) Country visits should wait until tangible results have been realized for demonstration of impact;
3) When countries start making progress with the project objectives, there will be a need for conferences to share experiences and ideas.

4. *Adaptation of work plan and actions of partners*

4.1 Activities

In the following tables the main activities of the NARS in the DMP/ORU Project and in the MUSCLUS project for 1998 are listed ((Table 4 and 5, respectively).

Table 4. Activities by NARS in the DMP/ORU Project in 1998.

Scale	Period	Activity
Burkina Faso		
Département	June - August	Identification of stakeholder goals
	June - December	Updating soil use maps, Collection of data on the credit situation, Updating soil maps
Village	June - August	Identification of stakeholder goals
	June - December	Updating soil use maps, Updating maps using ethno-classification of soils, Updating maps of forest zones, Updating maps of sorghum and millet production areas, Surveys on credit accessibility, Study of technology adoption, Market survey, Analysis of data and preliminary mode
Household	June - August	Identification of stakeholder goals
	June - December	Characterization, quantitative descriptions and economic analysis of agricultural activities, Model development, Preliminary report
Mali		
Cercle	June - August	Identification of stakeholder goals
	June - December	Elaboration of soil maps, Identification of technologies and causes of non-adoption, GPS Positioning
Commune	June - August	Identification of stakeholder goals
	June - December	Development of soil maps, Identification of technologies and causes of non-adoption, Analysis of data and development of models, GPS Positioning
Village	June - August	Identification stakeholder goals
	June - December	Development of soil and soil use maps, Studies of ethno-classification of soils, Analysis of data and preliminary development of models, Identification of technologies and causes of non-adoption, GPS Positioning
Household	June - August	Identification of stakeholder goals
	June - December	Choice of sample households, Measures of area and yeild by crop and soil type, Classification of soils (organic matter, texture, degradation), GPS Positioning, Analysis of data and preliminary development of models, Preliminary report.

Table 4. Activities by NARS in the DMP/ORU Project in 1998, continued.

Scale	Period	Activity
Niger		
Département	June - August	Identification of stakeholder goals
	June - December	Complete data collection
Arrondissement	June - August	Identification of stakeholder goals
	June - December	Data collection, Complete soil use maps, Inventory of technologies and constraints to adoption, Analysis of data and preliminary development of models
Village	June - August	Identification of stakeholder goals
	June - December	Soil and soil use mapping, Socio-economic characterization of households, Inventory of technologies and constraints to adoption, Choice of sample households, Analysis of data and preliminary development of models
Household	June - August	Identification of stakeholder goals
	June - December	Measures of area and yield by crop and soil type, GPS Positioning, Analysis of data and preliminary development of models, Preliminary report

Table 5. Activities by NARS in the MUSCLUS Project in 1998.

Scale	Period	Activity
Burkina Faso		
Village	July – December	Characterization, Elaboration of maps, Description of production systems, Constraints to production
Household	July – December	Characterization, Description of production systems, Constraints to production, Identification of stakeholder goals
Mali		
Village	July – December	Elaboration of maps, Identification of goals
Household	July – December	Description of production systems, Mapping, Constraints to production
Niger		
Département	July – December	Characterization, Constraints to production
Village	September – December	Elaboration of maps, Constraints to production

The following actions (some in addition to defined work plan) were identified for DMP/ORU and MUSCLUS project team members:

1998, June/July Finalizing (as far as possible for Niger) of draft multi-scale characterization reports by NARS

	July	Multi-scale characterization, and DMP/ORU-Progress and financial reports (Jan-July 1998) and tentative work plan for 1999 by NARS to ICRISAT;
		Financial report for MUSCLUS (1996, 1997) by NARS to ICRISAT;
		Discussion of NARS with stakeholders to redefine their goals
	August	Review of multi-scale characterization reports by ICRISAT
	Aug./Sept.	Field visit to NARS to discuss progress (e.g. goals) and reports (Table 6)
		DMP/ORU Second Progress report to ISNAR
	October	Backstopping for PhD studies of O. Samaké (Mali) and J.P. Tiendrebeogo by N. van Duivenbooden
	Nov./Dec.	Backstopping and working on models by T. Wyatt for one week at each DMP/ORU site
1999	January	DMP/ORU Progress and financial reports (Aug.-Dec. 1998) by NARS to ICRISAT
	March	DMP/ORU Third Progress report to ISNAR
	April	DMP/ORU and MUSCLUS Progress meeting in Burkina Faso (and DMP/IDRC pending funding)

Table 6. Tentative planning of backstopping mission of ICRISAT to NARS.

August 1998		September 1998	
23	Niamey-> Fada	1	Mopti -> Bamako
24	Fada + field visit	2	IER, Bamako-> Sikasso
25	Fada->Ouagadougou, INERA	3	IER-Sikasso
26	Ouaga->INERA-Tougan->Banh Field visit	4	Field visit -> Koutiala
27	Stakeholders Ouahigouya	5	Koutiala->Ouagadougou
28	Ouahigouya -> Bankass	6	Ouagadougou -> Niamey
29	Field visit, ->Mopti	15	Banizoumbou field visit, INRAN
30	Field visit	16	Niamey -> Tanda field visit
31	IER-Mopti, stakeholders	17	Gaya -> Niamey

4.2 Numbering of reports

To avoid confusion between the projects and facilitate reporting to donors, the various reports will bear the project name. For instance, the DMP/ORU-project reports will be numbered separately for each country; i.e. for Burkina Faso: DMP/ORU-Project Report B1 (until Bn); for Mali DMP/ORU-Project Report M1, etc., and for Niger: DMP/ORU-Project Report N1, etc.

5. Conclusion

The workshop successfully met its primary goal of providing the participants from different backgrounds and disciplines with the essentials of programming models for use in a decision support system for resource management. In addition, the results of the working groups provide the research teams with a better understanding of how to translate the stated goals of farmers, government and non-government development organizations and other stakeholders into quantifiable objectives that can be used with the models. This, in turn, will aid the teams in their discussions with the stakeholders to explain the capabilities and limitations of the approach and in collecting complementary data (at the district, village and household levels) to make the models operational.

Perhaps the most important result of the workshop is the focus and direction it provided for future activities. The group identified many of the goals that different parties hold and this provides a clearer basis for the development of the programming models, both the framing of the objectives and the description of the constraints. Many of these goals are actually development strategies (e.g., the construction of roads is not merely an end to itself) and the discussions in the working groups examined how these strategies and interventions can be modeled as development scenarios to help decision makers judge the effectiveness of their actions.

The group also discussed and began the process of linking the different scales of focus (household, village and district) together. The development of this methodology is the fundamental goal of the DMP/ORU project and the discussions of the workshop provide a basis for future work. The next ORU workshop, planned for April 1999, will continue this development. The different backgrounds and disciplines of the participants and the experiences of the three projects proved useful. An example of this linking of scales is the translation of scientific soil classification systems to farmer-recognized systems (ethno-classification of soils). The importance of this linkage is seen not only in that it permits the researcher to extrapolate between levels of focus but also that it facilitates the transfer of knowledge between farmer and researcher. The soil classifications are also one means of incorporating a Geographical Information System and further facilitating extrapolation and knowledge transfer.

Annex I. Distributed materials

The following materials were distributed to all: officially licensed GAMS software, demonstration versions for MUSCLUS and DMP/IDRC participants and professional versions with OSL (Optimizing Subroutine Library by IBM) for DMP/ORU participants, and diskettes with example GAMS models as presented by Drs. B. Barbier and T. Wyatt. In addition, the following documentation was distributed:

Brooke, A., D. Kendrick, and A. Meeraus, 1996. GAMS Release 2.25, a user's guide. GAMS Development cooperation, Washington, 295 pp.

GAMS, 1996. GAMS - The solver manuals. GAMS Development cooperation, Washington, 228 pp.

Hurn, J., 1989. GPS, a guide to the next utility. Trimble, Sunnyvale, 76 pp.

Lheriteau, F., 1998. Plan du cours du GPS en pratique. ICRISAT, Niamey, 4 pp.

van Duivenbooden, N., 1993. Impact of inorganic fertilizer availability on land use and agricultural production in the Fifth Region of Mali. II. Scenario definition and results.. Fertilizer Research 35: 205-216.

van Duivenbooden, N. & F.R. Veeneklaas, 1993. Impact of inorganic fertilizer availability on land use and agricultural production in the Fifth Region of Mali. I. Methodology and basic data. Fertilizer Research 35: 193-204.

For the participants from Kenya and Botswana:

van Duivenbooden, N., 1997. Exploiting multi-scale variability of land use systems to improve natural resource management in the Sudano-Sahelian zone of West Africa (MUSCLUS), Methodology and work plan.. Integrated Systems Project Report Series No. 1. ICRISAT, Patancheru 502 324, 40 pp.

van Ittersum, M.K., N. de Ridder, T. van Rheenen, E.J. Bakker, M.S.M. Touré, and K. Sissoko, 1997. Land use analysis using multiple goal linear programming; a course manual. Rapports PSS No. 31, IER/AB-DLO/DAN-UAW, Wageningen, the Netherlands. 148 pp.

For the participants from Burkina Faso, Mali, and Niger:

Bakker, E.J., T. van Rheenen, M.S.M. Touré, K. Sissoko, M.K. van Ittersum, et N. de Ridder, 1997. Analyse de l'utilisation de terre l'aide de la programmation linéaire à buts multiples. Rapports PSS No. 30, IER/AB-DLO/DAN-UAW, Wageningen, the Netherlands. 152 pp.

van Duivenbooden, N., 1997. Exploitation de la variabilité multi-échelle des systèmes d'utilisation des terres afin d'améliorer la gestion des ressources naturelles dans la zone soudano-sahélienne d'Afrique de l'Ouest (MUSCLUS), Méthodologies et plan de travail. Integrated Systems Project Report Series No. 2. ICRISAT, Patancheru 502 324, Andhra Pradesh, India, 42 pp.

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Annex III. Main program elements of the workshop

The main elements of the workshop are presented below. In the first week, GAMS theory sessions were alternated with practical sessions.

Monday, 8 June	Goals and objectives of this workshop Decision support systems and models at multiple scales Goals of stakeholders at different levels of scales Linear Programming with GAMS Linear Programming: 1) a farm in Burkina Faso
Tuesday, 9 June	Linear Programming: 2) Livestock and Forage, 3) Indices, 4) Production Functions, 5) Erosion
Wednesday, 10 June	Linear Programming: 6) Dynamic Models, 7) Recursive Models, 8) Village Level, 9) Social Groups
Thursday, 11 June	Linear Programming: 10) Risk, 11) Policy Experiments/Scenarios, 12) Simulations: EPIC and GIS Non-Linear Programming
Friday, 12 June	Multiple-Goal Linear Programming: 1) illustrated with a case in Mali, 2) Goals as constraints, 3) Measuring trade-offs, and 4) Multi-scale analysis
Saturday, 13 June	Goals of stakeholders at different levels of scales, revisited Time for planning and preparing project presentations
Monday, 15 June	Country Presentations, DMP/ORU Project Country Presentations, MUSCLUS Project
Tuesday, 16 June	Country Presentations, DMP/IDRC Project Working Group: Translation of stakeholder-goals into model-goals
Wednesday, 17 June	Working Groups: 1) Goals, interventions, and data requirements, 2) Linking different scales, 3) Use of ethno-classification of soils on DSS, 4) Updating work plans (by project), and 5) Linking DMP/IDRC with DMP/ORU and MUSCLUS
Thursday, June 18	Global Positioning System Library Planning of backstopping mission for ICRISAT
Friday, June 19	Global Positioning System Practical issues and miscellaneous Closing ceremony