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Use of Satellite-Derived Data to Improve Biophysical Model Output: An Example from Southern Kenya[1]

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ABSTRACT

The use of satellite data products produced by the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA) was explored to determine if these products could be used to provide plant growth model output for large landscapes. The use of satellite-derived data is generally advantageous because it is spatially dense (i.e., many measurements for a large landscape). Gridded daily temperature (0.1 x 0.1 degree) and rainfall (8x8 km), derived from the METEOSAT satellite, were used as inputs into the PHYGROW plant growth model for 30 pastoral households in southern Kenya. After model runs were completed, cokriging was used to determine if model output, coupled with NASA's Normalized Difference Vegetation Index (NDVI) product (a greenness index), could be used to create forage production maps for a large landscape. Cokriging is a geostatistical technique that allows one to take advantage of spatial autocorrelation (i.e., things closer together in space are usually similar than those farther apart), and the similarity between a small number of data points (model output in our case) and a one that is spatially dense (NDVI). Using cokriging, the majority of ten-day averages for year 2000 had moderate to high similarity between model output and NDVI. A comparison of model output and estimates from cokriging indicated that cokriging generally did a good job of estimating forage available for the 30 pastoral households. Mapped surfaces of the cokriging output successfully identified areas of drought in year 2000. Institutions at all levels could use these mapped surfaces as part of their GIS, which can then be linked to economic models, natural resource management assessments, or used for drought early warning systems.

INTRODUCTION

The ability to characterize the productivity of vegetation over large landscapes can be an important component of analyses to assess drought impacts, natural resource management options, environmental degradation, and economic impacts of changing technologies. Assessment of vegetation productivity over large landscapes in Africa has generally not been conducted on a historical basis. In many areas, the amount of time and resources required to do this type of assessment would tax the already limited budgets of the regional agricultural agencies. Therefore, the use of biophysical simulation models, driven by daily climatic variables (either historical or near real-time), may provide the means to accurately predict vegetation conditions. A problem with many simulation models is that most provide simulation output for a specific point. Ideally, one would want to simulate as many points as possible, but because climatic data for many areas is sparse, this may not always be a viable option.

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However, in the case of gridded data such as the daily rainfall estimates for Africa provided by NOAA (8km x 8km grid cells) the data can be so dense that the amount of time required for parameterization and computation for detailed biophysical modeling makes this option impractical with current computing power. Interpolation methods, such as ordinary kriging, or cokriging may allow the biophysical model simulations to be done for a minimal number of points, and then a surface map of the simulation output could be created for a region. These surface maps could then be used in any type of analysis that requires spatially explicit vegetation production across a region.
As an interpolation method, ordinary kriging can provide estimates for unknown points by using the weighted linear average of the available samples (in this case model simulation output) (Rossi et al. 1994). Kriging is often described as the Best Linear Unbiased Estimator (B.L.U.E.) (Isaaks and Srivastava, 1992). It is "best" because the variance of the errors is minimized, linear because the estimates are weighted linear combinations of the sample data, and unbiased in that the average error is equal to zero. Cokriging offers additional advantages over ordinary kriging. It involves the use of a secondary variable (covariate) that is cross-correlated with the primary or sample variable of interest. The secondary variable is usually sampled more frequently and regularly (Isaaks and Srivastava, 1992), thus allowing estimation of unknown points using both variables. This can aid in minimizing the error variance of the estimation (Isaaks and Srivastava, 1992).

The objective of this project was to evaluate the use of cokriging to create surface maps of forage production in Southern Kenya. The primary variable to be used in the evaluation will be simulation model output (total forage available for cattle) from the PHYGROW simulation model for a limited number of points (actual households) in Southern Kenya. Along with the primary variable, the Normalized Difference Vegetation Index (NDVI, a greenness index) product from NASA for the region will be used as a secondary variable in the cokriging analysis. The results of the analysis will be evaluated to determine if this methodology can be useful for providing spatially explicit estimates of forage production over a large landscape.

METHODS

Study Area

The area of interest for this project was the major pastoral region in Southern Kenya (Figure 1). Thirty unique pastoralist households (Figure 1) were chosen for this study. Plant community data, livestock stocking rates and movement rules, and soil data was gathered at each site for parameterization of the simulation model.

Simulation of Total Forage Available

The PHYGROW (Phytomass Growth Simulator) (Rowan 1995) model was used to derive the total forage available for cattle at each of the 30 households (simulation points) in Southern Kenya. PHYGROW is a hydrologic-based plant growth model that can simulate the growth of multiple plant species being grazed by multiple grazers for a specified ecological site or designated plant community having the same soil and weather features. PHYGROW simulates differences in ecological sites by varying the composition of the plant community, soil, grazer and weather parameters. Each plant community is composed of its major plant species, with each plant characterized by physiological response to weather, soil conditions, and grazing pressure. Biomass production and water balance are calculated daily for each site as a function of intercepted radiation, precipitation, and temperature. Plant community dynamics (growth, turnover, consumption, decay, and competition) progress with each day simulated, influencing forage production and water balance of the site.

Rainfall data used in the PHYGROW simulations for each georeferenced household was extracted from the satellite-derived NOAA daily rainfall estimate archive (ftp.ncep.noaa.gov/pub/cpc/fews/newalgo_est/). The grid cell size for this data is 8 km x 8 km. The NOAA rainfall estimates are derived daily for a large portion of Africa using an algorithm that combines METEOSAT 7 cold cloud duration data, weather station data, relative humidity and wind data (Herman et al. 1998). Minimum and maximum temperature for each household was extracted from another satellite-derived NOAA product (ftp.ncep.noaa.gov/pub/cpc/fews/daily_gdas_avgs/tmin/ and ftp.ncep.noaa.gov/pub/cpc/fews/daily_gdas_avgs/tmax/, respectively). The grid cell size for this data is approximately 11 km x 11 km.

PHYGROW simulations for each household were run for the period from Jan 1, 2000 to December 31, 2000. The output was then compiled to calculate average forage conditions for a household on each dekad (a dekad is defined as 10 –13 day period with 3 dekads in each month) during year 2000. Dekad averaging was chosen because this matched the way the NDVI data product is processed by NASA. Thus, the dekadal total forage available served as the primary variable in the cokriging analysis.

Normalized Difference Vegetation Index Data

NDVI data were chosen as the secondary or covariate data to determine if it would be feasible to use for cokriging analysis. NDVI is derived from data collected by NOAA Advanced Very High Resolution Radiometer (AVHRR) satellites, and processed by the Global Inventory Monitoring and Modeling Studies (GIMMS) at NASA. It is available to the public on the Africa Data Dissemination Service website maintained by the United State Geological Services (USGS) Earth Resources Observation Systems (EROS) data center (http://edcintl.cr.usgs.gov/adds/adds.html). The NDVI product provides a measure of the amount and vigor of vegetation at the land surface. The magnitude of NDVI is related to the level of photosynthetic activity in the vegetation seen by the satellite. Generally, higher values of NDVI indicate greater vigor and amounts of vegetation, thus making it an ideal candidate for cokriging of biophysical model output. NDVI is a nonlinear function that varies between -1 and +1. Values of NDVI for vegetated land generally range from about 0.1 to 0.7, with values greater than 0.5 indicating dense vegetation. Dekadal (10-day composites) NDVI images of Africa have been produced since 1982 for the entire continent of Africa. The data are spatially dense with a grid cell size of 8km x 8 km

Co-kriging Analysis

Cokriging on the total forage available (primary variable) and NDVI (covariate) across the region were conducted using the GS+ software package (Version 5.1f, Gamma Design Software). The semivariance analysis module of the software was used to calculate the variogram models for total forage available, NDVI, and the cross semivariance between total forage available and NDVI. The resulting variogram models were then used in the kriging module of the software to develop the cokriged surfaces, and the cross validation analysis. The cokriged surface outputs were imported into ArcView software for the development of forage production maps.

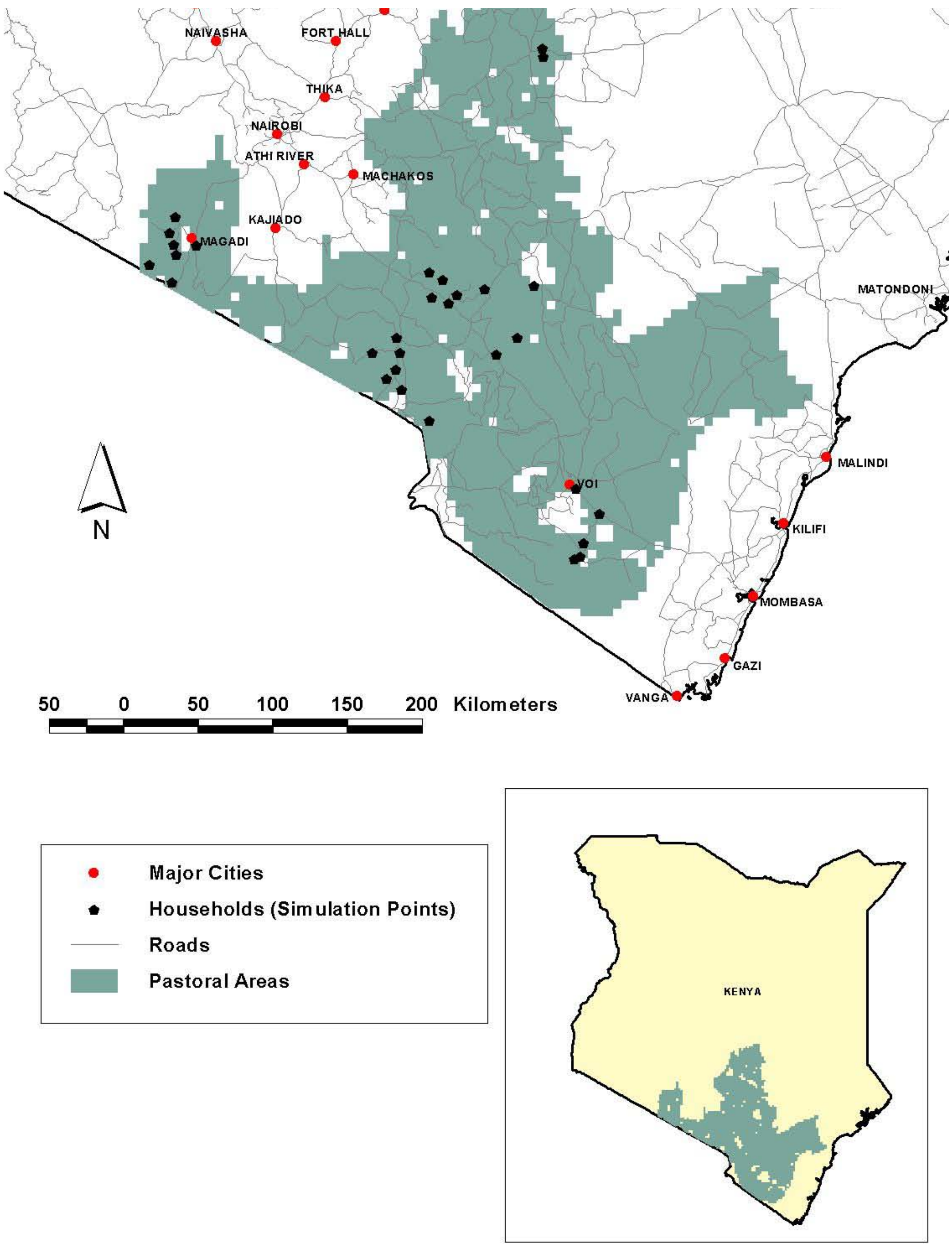


Figure 1. The location of pastoral areas and households in Southern Kenya where cokriging analysis with PHYGROW model output and NDVI was tested.

RESULTS AND DISCUSSION

Correlation Analysis

One of the first steps in assessing the feasibility of cokriging using NDVI as a secondary variable with model output was to examine whether a relationship existed between the two variables. A Pearson's correlation analysis was conducted using the 10-day average forage production for each given dekad versus the NDVI for the same dekad or the previous dekad. Results of the correlation analysis indicated that for the majority of the dekads in year 2000, the 10-day average total forage available across the 30 household points had a similar pattern to that of NDVI at these same household points (Table 1). For several of the dekads evaluated, NDVI for one of the previous dekads was more highly correlated to total forage available than NDVI during the dekad being evaluated (Table 1). This may indicate that plant growth in the PHYGROW model lags behind actual greenness at the observation points. Vegetation in many of these areas will green up very quickly after rainfall, but this doesn't always equate to large increases in plant biomass.

Cokriging Analysis

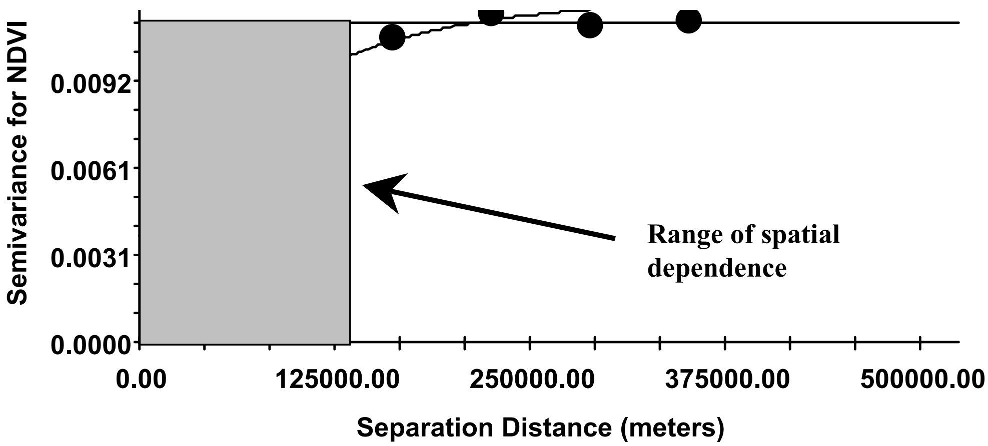
Cokriging analysis requires three major steps before maps can be created. These include semivariance analysis for the primary variable (in this case, total forage available for cattle), semivariance analysis for the secondary variable (in this case, NDVI) and cross semivariance analysis. Semivariance analysis for both the primary and secondary variable allows one to assess the dissimilarity of data points to the distance (spatially) that separates them (Johnston et al. 2001). In doing this, one can determine the degree of spatial autocorrelation (i.e., points closer together are more similar than those far apart and are not independent) and model the spatial relationships in the dataset (Figure 2). The cross-semivariance analysis is similar to semivariance analysis, but the spatial relationship between two variables is examined rather than one. In both the semivariance and cross-semivariance analysis, a mathematical model is created that captures the spatial relationship. Statistics can be calculated from the mathematical model to determine how well the spatial relationship has been explained (Figure 2).

Once the semivariance analysis is completed, cokriging using the semivariance models can be conducted. This analysis will create a surface map of the primary variable. To assess how well the cokriging analysis predicts values at unknown locations within the mapped surface, cross-validation analysis is used. In cross-validation analysis, each measurement for a household in the area of interest is individually removed from the domain and its value estimated via cokriging as though it were never there. This allows one to compare the actual versus the estimated values for each household. A linear regression is then done to determine how much of the variability in the household forage values simulated by PHYGROW are explained by the cokriged estimates. The higher the r^2 of the linear regression, the more variability that is explained and thus, the more successful the cokriging model is at predicting unknown points.

Since the majority of the dekads examined in this study had moderate to high correlation between the forage and NDVI, four dekads were selected for further discussion in this paper to alleviate redundancy. These dekads were as follows: 1) February, Dekad 2; 2) May, Dekad 1;

Table 1. Results of correlation analysis (r) to determine if a relationship existed between the PHYGROW model output (primary variable) and NDVI. Correlation analysis was conducted for total forage available for cattle for each simulation dekad (10 day average) versus the NDVI value for the same dekad or previous dekad. Shaded dekads below were selected for detailed review for this paper. Correlations marked with a "*" indicate statistical significance (α=0.05).

Simulation Dekad	**Correlated NDVI Dekad**	**Correlation (r)**
January, Dekad 1	January, Dekad 1	0.545*
January, Dekad 2	January, Dekad 2	0.734*
January, Dekad 3	January, Dekad 3	0.812*
February, Dekad 1	February, Dekad 1	0.843*
February, Dekad 2	February, Dekad 2	0.857*
February, Dekad 3	February, Dekad 3	0.811*
March, Dekad 1	February, Dekad 3	0.804*
March, Dekad 2	March, Dekad 2	0.765*
March, Dekad 3	March, Dekad 2	0.774*
April, Dekad 1	April, Dekad 1	0.624*
April, Dekad 2	April, Dekad 2	0.669*
April, Dekad 3	April, Dekad 3	0.822*
May, Dekad 1	April, Dekad 3	0.832*
May, Dekad 2	May, Dekad 2	0.696*
May, Dekad 3	May, Dekad 3	0.807*
June, Dekad 1	May, Dekad 3	0.800*
June, Dekad 2	May, Dekad 3	0.787*
June, Dekad 3	June, Dekad 3	0.475*
July, Dekad 1	July, Dekad 1	0.665*
July, Dekad 2	July, Dekad 1	0.647*
July, Dekad 3	July, Dekad 3	0.441*
August, Dekad 1	August, Dekad 1	0.526*
August, Dekad 2	August, Dekad 2	0.630*
August, Dekad 3	August, Dekad 3	0.744*
September, Dekad 1	August, Dekad 3	0.719*
September, Dekad 2	September, Dekad 2	0.788*
September, Dekad 3	September, Dekad 2	0.773*
October, Dekad 1	October, Dekad 1	0.699*
October, Dekad 2	October, Dekad 2	0.827*
October, Dekad 3	October, Dekad 2	0.795*
November, Dekad 1	October, Dekad 3	0.565*
November, Dekad 2	November, Dekad 2	0.438*
November, Dekad 3	November, Dekad 2	0.265
December, Dekad 1	December, Dekad 1	0.035
December, Dekad 2	December, Dekad 1	0.112
December, Dekad 3	December, Dekad 3	0.066



Exponential model (Co = 0.0038; Co + C = 0.0122; Ao = 95000.00; r2 = 0.967; RSS = 9.358E-07)

Figure 2. An example of a semivariance model used in the cokriging analysis of NDVI. The gray shaded area depicts the range of spatial dependence for NDVI in this dataset. Points beyond this distance are not similar and can be described as random. In this example, an exponential model function was used to capture the spatial autocorrelation and was successful in explaining the spatial dependence as indicated by the high r^2 of 0.967.

3) July, Dekad 2 and 4) October, Dekad 3. These dates were chosen to reflect the change in total available forage that occurred over this time period. The semivariance models and cross-validation results for each dekad will be discussed below.

February 2000, Dekad 2. For the households simulated in Southern Kenya for the second dekad in February 2000, total forage available for cattle ranged from 1,466 to 4795 with an average of 3085 kg/ha. The semivariance analysis model for total forage available did an excellent job of explaining the spatial variability in the total forage available for the 30 households across the landscape ($r^2 = 0.90$). The semivariance analysis for NDVI (same dekad) had similar results ($r^2 = 0.96$). This resulted in the cross-semivariance model having a high r^2 (0.83). Since the cross- semivariance model explained a large degree of spatial variability between forage and NDVI across the landscape, then the quality and reliability of the surface map should be good. The resulting interpolated surface (Figure 3, February 2000 Dekad 2) captured the range of total forage available output by the model. The cokriging analysis did a good job of predicting total forage available for the simulation points. The cross-validation regression showed a very reasonable correspondence between cokrig-estimated total forage available and the PHYGROW simulated total forage available for the household points (Figure 4, r^2=0.78, standard error of prediction=495 kg/ha)

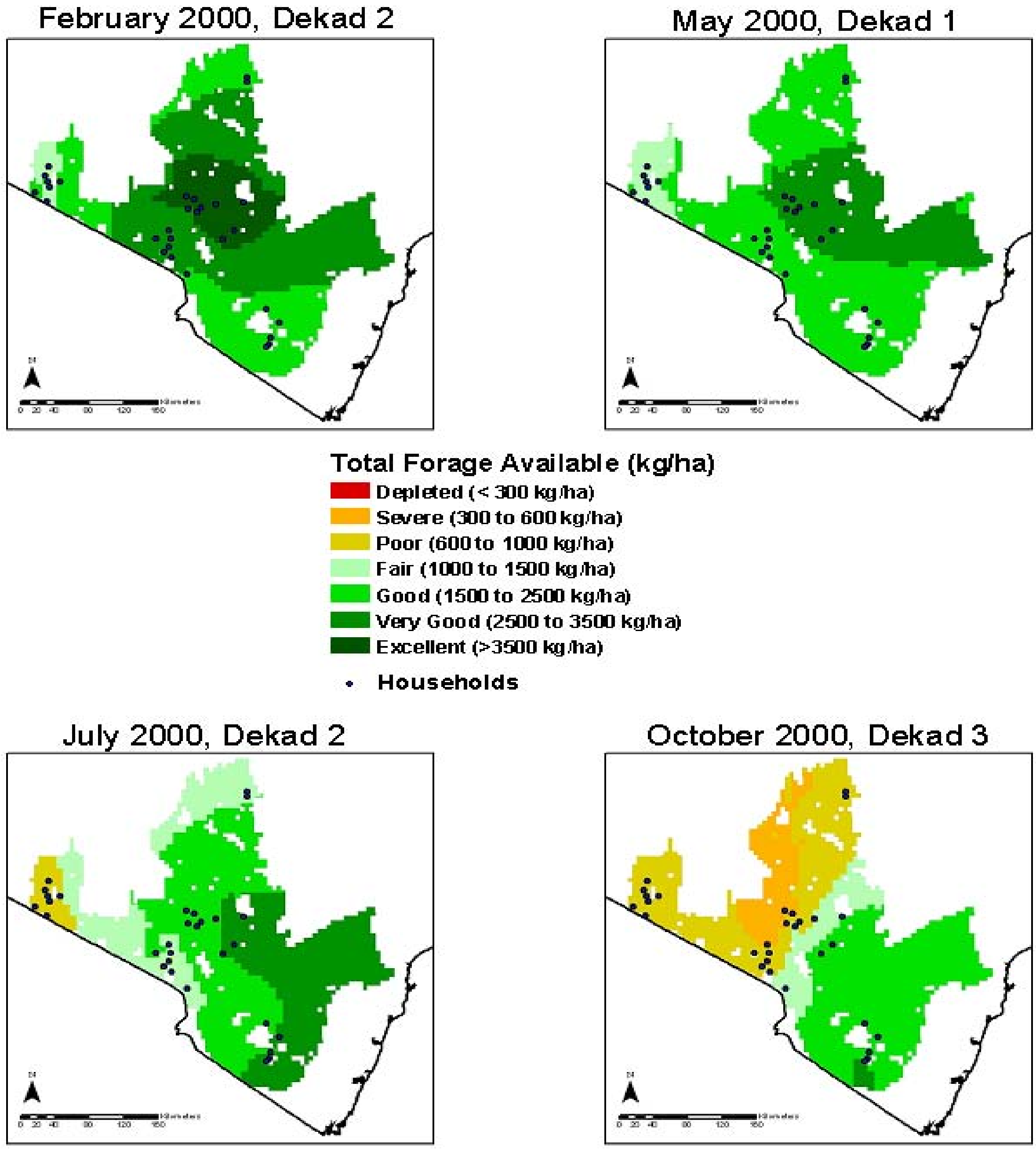


Figure 3. Maps depicting total forage available for cattle (kg/ha) generated by the cokriging analysis for selected dekads (10 day periods) during year 2000 in Southern Kenya.

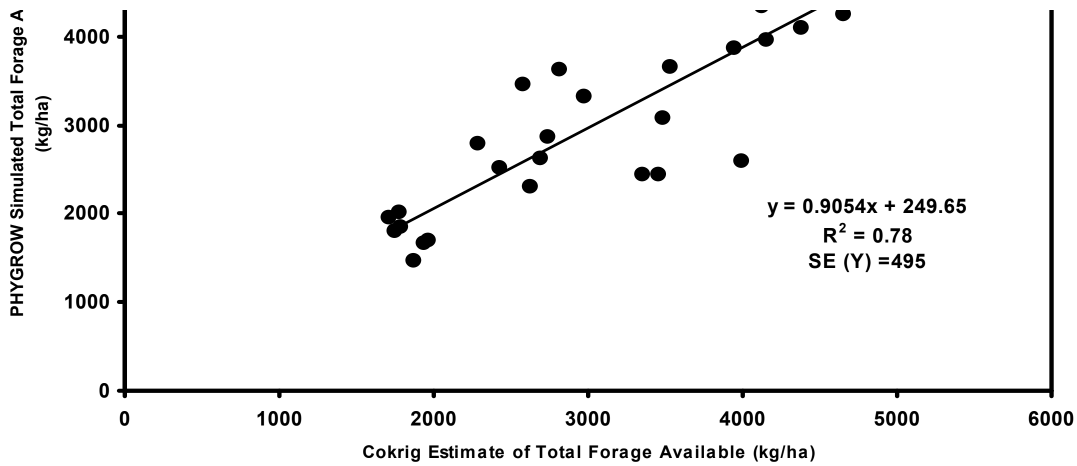


Figure 4. Cross-validation results for the comparison of cokriged derived estimates of total forage available versus the actual PHYGROW simulated total forage available for dekad 2 in February 2000. Cross-validation model r^2 and standard error of prediction [SE (Y)] are given.

May 2000, Dekad 1. Average total forage available for cattle during the first dekad in May 2000 ranged from 1055 to 3379 kg/ha with an average production across the 30 simulation points of 2065 kg/ha. This was an almost 1000 kg/ha decrease in total forage available since dekad 2 in February described above. The semivariance analysis model for total forage available had a moderately high r^2 (0.77) indicating that the semivariance model explained a large proportion of the variability in total forage available across the landscape. The semivariance analysis for NDVI (last dekad of April) was not quite as successful (r^2 = 0.57). However, the cross-semivariance model explained a higher proportion of the spatially variability (r^2 =0.81) than the total forage available and NDVI semivariance models individually. As discussed previously, the greater the proportion of spatial variability explained by the model, the higher the quality of the cokriged surface (Figure 3, May 2000, Dekad 2). The cross-validation regression showed a high degree of similarity between the cokriged estimates and the model simulated total forage available for the 30 household points (Figure 5, r^2=0.79, standard error of prediction=321 kg/ha).

July 2000, Dekad 2. Total forage available for households simulated in Southern Kenya for the middle dekad in July 2000 ranged from 771 to 2798 kg/ha with an average of 1729 kg/ha. These amounts were around 300 to 350 kg less than that during early May. Both total forage available and NDVI (July, Dekad 1) exhibited a high degree of spatial autocorrelation and the semivariance models were successful in capturing the variability in each of these across the landscape as seen in the high r^2 values for the models (0.71 for total forage available and 0.92 for NDVI). This indicates that there

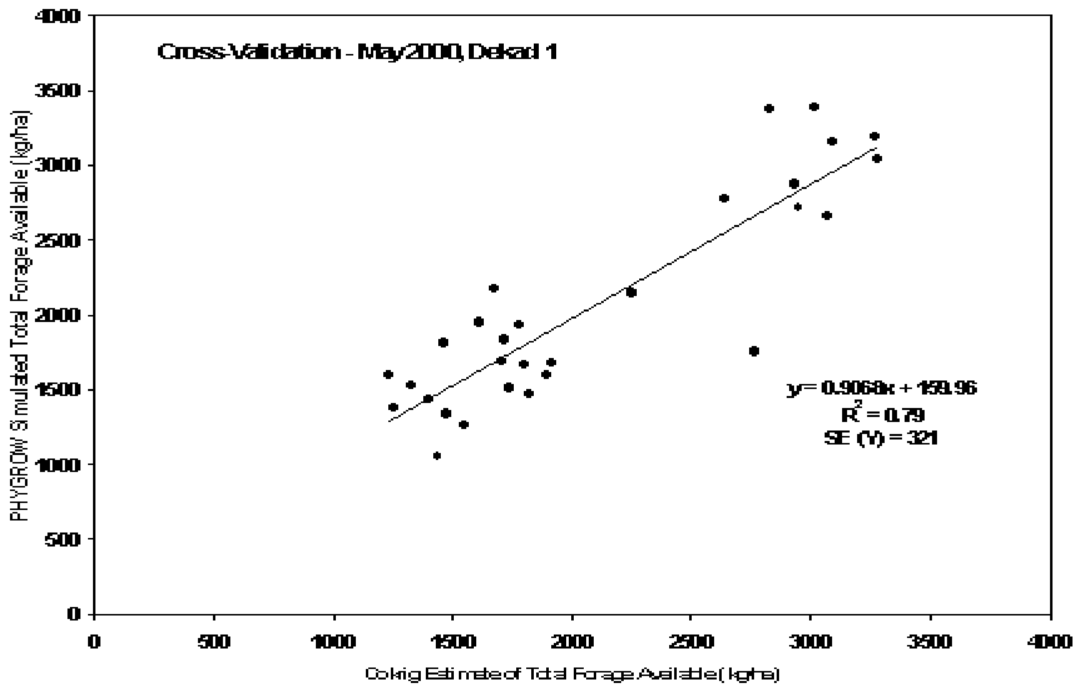


Figure 5. Cross-validation results for the comparison of cokriged derived estimates of total forage available versus the actual PHYGROW simulated total forage available for dekad 1 in May 2000. Cross-validation model r^2 and standard error of prediction [SE (Y)] are given.

was a higher degree of spatial autocorrelation among the household points during this period. Semivariance analysis for NDVI covariate (first dekad of July), using the same lag interval, also had good results (r^2 = 0.92). This high degree of spatial autocorrelation for both variables resulted in the cross-semivariance model having a high r^2 (0.83), thus improving the reliability of the cokriged map (Figure 3, July 2000, Dekad 2). The cross-validation results were similar to those discussed previously for the other dekads (Figure 6, r^2=0.77, SE prediction=343 kg/ha).

October 2000, Dekad 3. Total forage available for households simulated for the last dekad in October 2000 ranged from 412 to 2607 kg/ha with an average of 1128 kg/ha. These amounts were around 200 to 500 kg less than that during mid-July. The semivariance model for this time period was able to explain a large portion of the spatial variability in total forage available among the 30 households (model r^2 =0.84), and the model for the NDVI covariate did an even better job, explaining almost all of the variability in NDVI across the landscape (model r^2 =0.99). The cross-semivariance model for total forage available and NDVI also did an excellent job of explaining the spatial variability (mode r^2 =0.97) resulting in a cokriged surface that clearly delineates differences in forage across the landscape (Figure 3, October 2000, Dekad 3), especially those that are susceptible to severely low forage conditions (300 to 600 kg/ha). The cross-validation regression showed a similar lower degree of correspondence between cokrig-estimated total forage available and the simulated total forage available for the household points (Figure 7, r^2=0.70, SE prediction=329 kg/ha) as that seen in the previous periods.

DISCUSSION

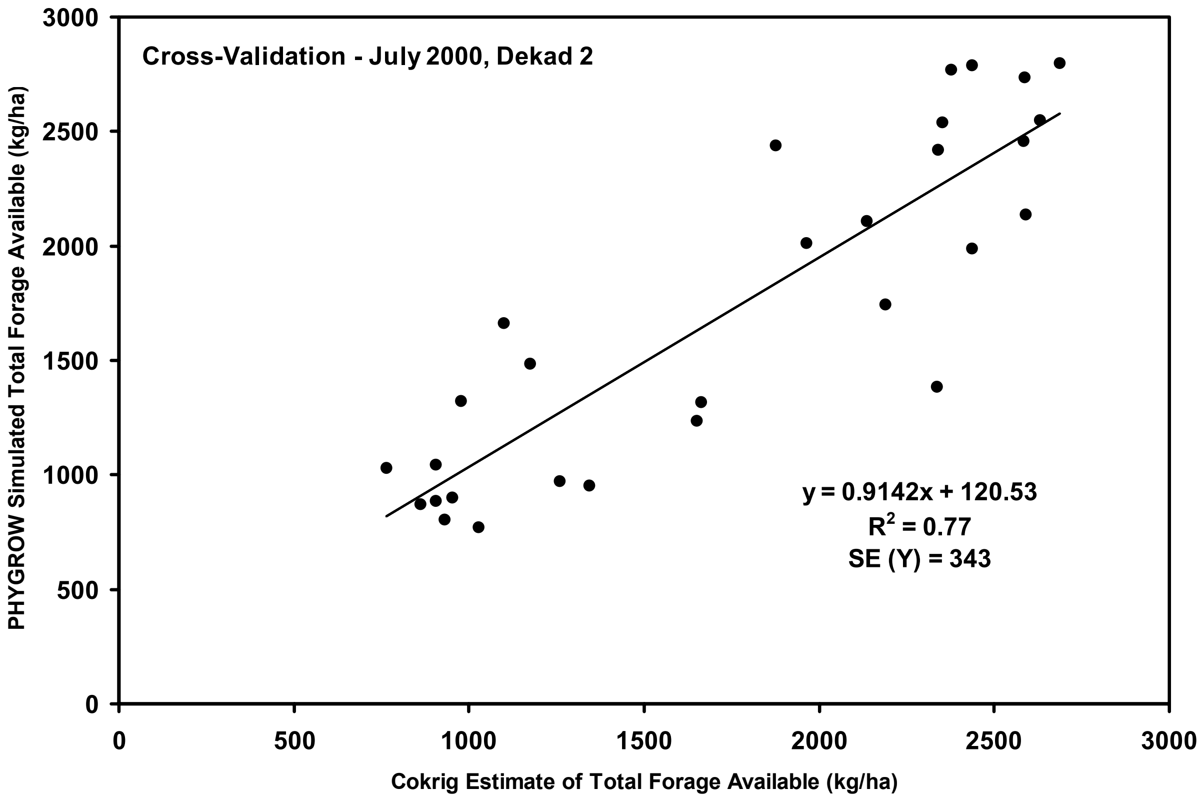


Figure 6. Cross-validation results for the comparison of cokriged derived estimates of total forage available versus the actual PHYGROW simulated total forage available for dekad 2 in July 2000. Cross-validation model r^2 and standard error of prediction [SE (Y)] are given.

For the majority of the dekads reviewed in this analysis, the total forage available output from the PHYGROW model was correlated with NDVI at the household points. Cokriging was successful in creating surfaces maps that provided spatially explicit estimates of forage production across the landscape and these estimates appeared to be reasonable when evaluated with cross validation. Interviews with regional specialists indicated that these maps captured the changing forage conditions that occurred in the region.

Maps such as these can have tremendous value for drought early warning, natural resource impact assessments, and environmental degradation. In the case of drought early warning, cokriged maps could be created on a near real time basis, thus allowing users to identify areas susceptible to drought. The maps in Figure 3 provide a time series that clearly show areas that may be susceptible to low forage conditions due to drought, overgrazing, or a combination of these factors. Also, the use of spatially explicit climate data served by NOAA on a daily basis to drive the PHYGROW model (or any other biophysical model), coupled with the NDVI data that is served by NASA every 10 to 13 days, makes near real time compilation of these maps a reality. These maps could then be disseminated to various levels of government, responsible agencies, NGO's, and to the pastoralists grazing in the regions, thus providing them with information to improve decisions regarding livestock and people.

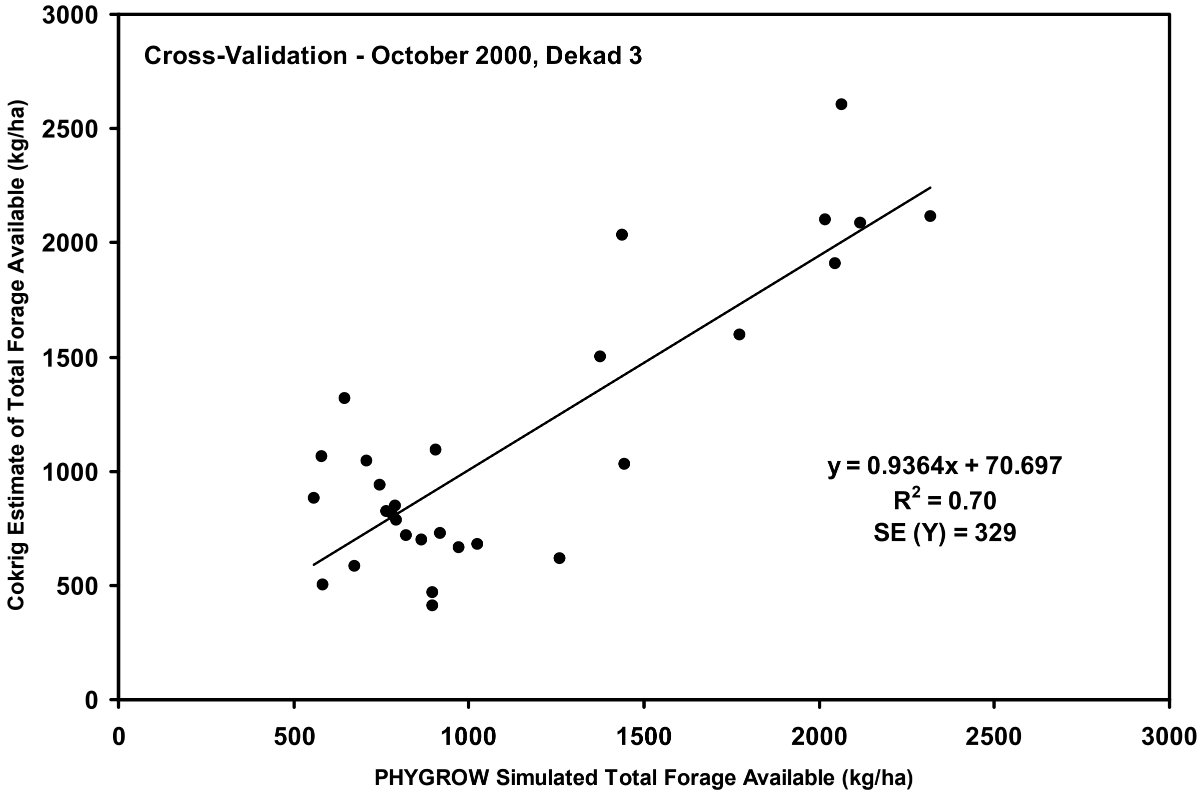


Figure 7. Cross-validation results for the comparison of cokriged derived estimates of total forage available versus the actual PHYGROW simulated total forage available for dekad 3 in October 2000. Cross- validation model r^2 and standard error of prediction [SE (Y)] are given.

With regard to natural resource impact assessment and environmental degradation, cokriging may be a viable option for assessing the impact of changing technologies or changes to landscapes over time. Historical climate data for weather stations in a region could be used to drive the biophysical models, and if the output is correlated with NDVI for the region, spatially explicit maps of changes in vegetation over time could be developed. This method could offer advantages over the traditional method of assigning point based model output to homogenous land units such as soil type (Bouman, 1995) because the increased spatially variability brought about by the smaller scale unit of the NDVI better captures the spatial variability that exist across a region. Cokriged output could then be used in area-weighted assessments of forage production needed by economic models in impact assessment or used to identify areas where environmental degradation has occurred over time.

Improvements in cokriging output could also be made from investigating other secondary variables (covariates). For several of the dekads investigated, there was a low correlation between model output and NDVI. Other spatially dense data could be used or combined with NDVI to create a spatially explicit index variable that could improve the cokriging output. For example, elevation might be combined with NDVI data and rainfall data for the region to create a new covariate that captures more spatial variability, thus improving the surface mapping capabilities using cokriging

CONCLUSIONS

Cokriging using simulation output and NDVI appears to show promise in creating mapped surfaces of available forage for a large landscape in Southern Kenya. The cokriging analysis was successful in spatially representing the changes in forage production across the region. Cross validation analysis indicated that the cokriging provided very reasonable estimates of forage production when compared to PHYGROW model output. The cokriged maps were also successful in identifying the temporal changes in forage production and successfully identified areas of severe forage conditions in late October 2000. Mapped surfaces such as these could be incorporated into a geographic information system (GIS) for use in drought early warning, natural resource impact assessment and environmental degradation analysis. Institutions at all levels could use these mapped surfaces as part of their GIS, thus allowing them to link this information to economic and other natural resource models to improve decision making.

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Application Of Rainfall Analysis, Biophysical Modeling And Gis To Agroclimatic Decision Support In Madiama Commune, Mali (West Africa)[1]

Oumarou Badini[2] and Lassana Dioni[3]

ABSTRACT

An analysis and understanding of the intimate relationships between the weather, soils and agricultural production systems, and especially the complexities associated with the variability and distribution of rainfall and soil type are essential elements in improving crop production and agricultural planning decision making. In the present paper, knowledge from the analysis of historical rainfall records and predictive information based on the "response farming" approach have been combined with GIS and biophysical simulation modeling of soil water balance and crop production functions to assess the agroclimatic performances of a 90-day millet cultivars in Madiama, Mali. For each of two groups of rainfall onset date (early and late), the crop water stress, crop yields as well as overall stress indices in reference to yield potential permitted by different soils under low and optimum nitrogen input levels have been simulated, analyzed and mapped to illustrate how this approach could work for advisors and farmers in the study region. From the analysis of the rainfall records good relationships are found between rain onset dates and seasonal rain amounts and duration. Also, the Cropping System Simulation Model (CropSyst) used in combination with the weather analysis is found to be a useful tool in aiding determine soil suitability of crops, screen technologies and build recommendations packages for a response farming type approach.

INTRODUCTION

The commune of Madiama, which is the study area, is about 25 kilometers from Djenné (capital of the administrative Circle) and 120 kilometers southernmost of Mopti (capital of the 5th Region of Mali). It lies between 13° 45 N to 13° 52 N, and 4° 22 W to 4° 30 W. It is part of the Niger Delta region and located in the north-central part of the republic of Mali. The commune that comprises 11 villages has a total land area of 16970 hectares (169.7 square kilometers), or about 66 square miles. Madiama region is characterized by a short rainy season (3 to 4 months), considerable variability in the rainfall amount and distribution,

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with high radiation loads and temperatures during the growing season which influence annual crops and pastures potential because of the continuous and high evaporative demand from the atmosphere. Like in other areas of the West African semi-arid Sahel region, the study zone has suffered diminished food production on a per capita basis since the early 1970's.

Although exacerbated by population growth, the fundamental problem is physical. Long-term rainfall throughout the region declined dramatically in the early 1970's and has not since returned to earlier levels. Seasonal rainfall regimes are inherently variable and uncertain, and our science has not been able to effectively cope with it.

The need for a secure food supply must be carefully considered when evaluating sustainable agricultural practices for the region. Farmers in the region are more concerned with the avoidance of disaster years than aiming solely at higher yields. They view each year as different and unique. They consider rainfall as the principal factor determining crop production. Low yields are often related to late start of rains, a drought period after planting or too much rain in late July and early August, impeding grain development. In good rainfall years, production levels are sufficient regardless of land quality where crops can be grown. Consequently, one of the key impediments that limit productivity and food security for rainfed agriculture is seasonal variability and uncertainty of rainfall. Both deficit and excessive rainfall can create serious management problems for rainfed farmers, as there are important differences in the production potential in wetter years versus drier years. Therefore, a better understanding and early predictability of the rainfall potential for a given season could be an important step in designing appropriate strategies for improved food production in the west African Sahel region. There is a pressing need to identify and promote dry land agriculture practices that better utilize the available rainfall.

In this uncertain environment where annual crops' performances vary greatly from season to season, subsistence farmers have traditionally responded by applying some management decisions to conform with projected rainfall – but with some limited success. Many farmers plant dry, mix varieties and follow varying management strategies to minimize risks. Still, in years of scarce rainfall the precarious balance between subsistence and survival is broken and very often hunger and starvation are the main corollaries. Efforts by agricultural scientists and farmers to determine optimal farming technologies and cropping systems are greatly complicated by the complex nature of the combination of seasonal rainfall variability, crop cultivars, management practices and soil types. Efficient methods that introduce flexibility in the cropping system to more closely match variation in seasonal rainfall with feasible technologies most likely to approach optimal resource and management combinations for given soils are needed in order to contribute to a more secure and reliable food supply.

Previous analyses of the historical daily rainfall data for location in Niger, Burkina Faso, Kenya (Sivakumar, 1988, 1990, Ian Stewart, 1988) suggest that prediction of the rainy season potential in order to tailor optimal cropping systems during the growing season may be possible. It was also suggested that application of this information could be further improved by integration of this analysis with soils and crops information and the use of cropping simulation models. Cropping systems simulation models can play a strategic role in evaluating existing and alternative farming systems in high-risk rainfall variability prone dry land agriculture. Today, we possess the needed historical records (e.g. rainfall), research tools and computing power to sort through the complexities and give farmers the information they need to greatly increase their yields and returns per unit of rainfall received.

We can introduce new technologies suitable to biophysical conditions (weather, soils, crops) that may strongly affect the risk structure. Assessment of soils, weather and management schemes using computerized tools such as simulation models and GIS could help in screening suitable technologies dependent on weather regime and soil types. This in turn may call for changes in recommended practices and decision-making processes. Furthermore, when our recommendations are finalized, we can utilize our computerized datasets (displayed for example as maps) to inform the farmers – on a localized basis, and clear terms than do their tradition – of the real risk structure they are facing and the possible technological responses based on the weather patterns and rainfall onset date of a given season.

In the present work, knowledge from the analysis of historical rainfall records and predictive information based on the "response farming" approach (Ian Stewart, 1988) have been combined with GIS and biophysical simulation modeling of soil water balance and crop production functions to assess the agroclimatic performances of some millet cultivars in Madiama. For each of two groups of rainfall onset date (early and late), the simulated crop yields, crop water stress, as well as overall stress indices in reference to yield potential permitted by different soils under low and optimum nitrogen input levels have been computed and mapped.

The overall purpose of this study is to show the potential for long-tern and short-term rainfall probability analysis on the basis of onset dates, and the applicability of simulation modeling to agroclimatic analysis and the choice of technologies for tactical response farming in Madiama area. The useful biophysical information generated from these analyses could guide the choice of optimum cropping systems and is simple to transmit to both advisers and farmers. This screening methodology used in the present study aims at reducing the cost and time required to develop and choose farming systems technologies to be included in a tactical response farming during the growing season. Our contribution, which is a work in progress, seeks to minimize risks of cropping failure as much as possible by using predictive capabilities based on dates of onset of rains and generating information that could help in tailoring appropriate recommendations for a given cropping season.

METHODOLOGIES

1. Long-term and seasonal analyses and characterization of Rainfall

a. Database

Historic daily weather data (solar radiation, rainfall, air temperature) from 1950 to 1999 for Mopti, Djenné, Sofara were obtained from the Meteorogical Service of the government of Mali. An automatic weather station with data logger was installed by SANREM in Madiama since June1999. The station allows the recording of daily and hourly data on rainfall amount and intensity, air and soil temperatures, solar radiation, wind speed and relative humidity. Individual rain gauges are also installed in each of the other 10 villages of the commune. These compiled weather data were used for the rainfall analyses and the simulation modeling.

b. Long-term Analysis

To understand and characterize the long-term agro-climatic conditions in Madiama, the general trend of historical rainfall amounts from 1950 to 2000 has been determined and plotted. To take into account the change in rainfall patterns since the droughts of the 1970's in the Sahel region, the period 1950 to 2000 was divided into 1950-69 and 1970-00, and annual averages were computed for the two periods. Then the most recent records from 1970 to 2000 were retained as most representative actual weather conditions in the study area. Using the last 31 years of records from 1970 to 2000, long-term rainfall amounts and variability are described and assessed through the analysis of annual and , monthly totals. Also, a dekadal (every ten-day) reliability analysis was done from the daily rainfall and confidence limits (median, lower and upper quartiles) statistics plotted to represent trends throughout the year. An estimate of potential evapotranspiration (PET), computed from the model CropSyst, was superimposed on the ten-day graph, which allows an examination of periods of adequate rainfall and risk periods.

c. Seasonal Rainfall Predictions and Reliability Analysis

In order to determine agroclimatic indicators that would help foster decision that would guide the choice of management practices in response to seasonal rainfall variability the "response farming" approach which is to predict and respond has been evaluated (Stewart, 1987). Linear relationships between date of onset of rains to length of growing season and total rainfall amounts have been evaluated and two groups of onset dates identified. To investigate the onset relationships for each season, the records from 1970 to 2000 was analyzed, to quantify possible ranges of rainfall behavior and probabilities within ranges. The analysis consists of 3 parameters computed from the daily rainfall data in each year of the 31-year record from 1970 to 2000:

- The dates of onset and end of rains – the date of onset is considered as the first day after June 1st when stored soil water equals at least 40 mm (Stewart, 1987) and/or when rainfall accumulated over 3 consecutive days is at least 20 mm and when no dry spell within the next 30 days exceed 7 days. The final date of rains is considered as that date after September 1 following with no rain occurring over a period of 20 days (Sivakumar, 1988).

- The length (duration) of the rainy season for each year – this duration is taken as the number of days from the date of onset to the final rain date.

- The seasonal total amount of rains at different phases and all year long is the total rainfall from onset to end of rains.

An early and late onset dates were determined by considering the median date of onset from the 31-year rainfall record. Dates before the median date were considered early and those after the median were considered late onset dates.

2. Simulation Modeling and Agroclimatic Assessment

The cropping systems simulation model CropSyst was used in the present study. CropSyst is a multi-year, multi-crop, daily time-step simulation model developed to serve as an analytical tool for investigating the effect of cropping systems management on crop productivity in relation to environmental patterns such as soils and weather. The model integrates several components and different management options, and simulates the soil water budget, soil-plant nitrogen budget, dry matter production, yield, etc. Details on management options and model components can be found in the model's user's manual (Stöckle and Nelson, 1993) and elsewhere (Stöckle et al., 1994, Badini et al., 1997).

Although many other biophysical parameters could be included to evaluate the suitability of crops in a given environment, in the present work the model was used to only assess the water-limited growth environment of a 90-day millet cultivars and the impacts of nitrogen fertilization in years of early and late onset of rains. The components of CropSyst used are: the soil water balance and the crop growth models.

a. Database

To be able to run CropSyst, input data describing the location, weather, soils, crops and management from the study site were used.

Location and weather database – parameters characterizing the site of interest are name (Madiama), latitude, longitude, elevation and daily rainfall as well as minimum and maximum temperatures. Actual weather data from 1970 to 2000 were used.

- Soil database – using data provided by the Soil Survey of Madiama Commune (O. Badini and L. Dioni, 2001) and seasonal monitoring data from the site, a soil parameter file was constructed for each of the 7 land units identified in the commune. These units are: hydromorphic flood plains (*unit Ci*), hydromorphic alluvial levees or sand banks (*unit Tr*), old levees and alluvial terraces (*unit t1*), old alluvial plains and terraces (*unit Ca*), the plains of sandy to loamy materials (*unit t2*) and land underlain by laterite (*unit Vi*). Chemical tests data as well as soil physical data on texture, bulk density, field capacity and permanent wilting point (PWP) water content for each unit were provided.

- Crop database – from our existing database, a 90-day millet cultivar called *Sagnori* in local language was used. Calibration for the millet cultivars was performed using field data collected in Madiama on phenological events (emergence, flowering and maturity dates), maximum rooting depth, maximum Leaf Area Index (LAI) yield and harvest index data.

- Management database – two fertilization levels were used - no nitrogen (0 N) to represent traditional low input system and optimum nitrogen (N) to represent improved systems. A millet monoculture was simulated with a 10% surface residue and a simple ridging system with soil conservation practice factor P set to 0.9.

b. Simulation and output analysis

After calibration of the crop cultivars, the databases for soils, weather, crops and management have been combined through a simulation rotation table in CropSyst to simulate soil water balance and crop yield potential in years of early and late rain onset dates as a function of soil types and nitrogen (N) input levels. The outputs of the soil water budget and the crop production functions obtained from the simulation were used either singly or in combination to compute agroclimatic indices that helped determine the development and the water-limited growth environment of the millet cultivars *Sagnori*. The biophysical decision indicators used are:

- The crop water stress index, which is the ratio between actual transpiration (Ta) and maximum (potential) transpiration (Tmax) during the crop growth cycle. This quantity is used as indicator of the plant response to environmental conditions. The values range from 0 to 1. Where 0 is no stress and 1 is maximum stress. Under very limited water conditions or high crop water demand, the deficit can be so severe as to cause crop failure as thus the ratio becomes close to1.

- The crop yields and overall stress index in reference to yield potential permitted by different soils under low and optimum nitrogen input levels have been computed. In the present study, the overall stress index (OSI) corresponds to (1- ratio of actual yield to maximum yield). OSI integrates light, temperature, water and nitrogen stress indices. A value of 0 is no stress and 1 is maximum stress. This index is indicator of the riskiness of growing a given crop in a given environment and can help in the choice of technologies and crops in relation to onset dates.

RESULTS & DISCUSSIONS

1. Rainfall long-term and seasonal analyses and characterization

1.1. Long-term Rainfall Patterns

a) <u>Rainfall Amounts and Distribution</u>

In areas such as the study region where pronounced seasonal patterns of rainfall are influenced by changes in solar energy and pressure patterns (Sivakumar et al., 1984), mean annual rainfall could help provide useful assessment of agricultural potential. The annual rainfalls, the long-term mean and the general rainfall trend in the area of Madiama in the period from 1950 to 2000 are plotted in Figure 1. The annual rainfall in the commune and surrounding area varies considerably from year to year, a very common characteristic in the semi-arid tropics. From 1950 to 2000, the mean annual rainfall is 544 mm. The lowest annual rainfall of 274 mm was recorded in 1987 while the highest annual rainfall in the past 51 years was 914 mm, received in 1957.

Figure 1 shows that years of above average and below-average rainfall tend to come in clusters as seen throughout the Sahel. With an average of 636 mm, the annual rainfalls during 1950-69 were consistently above the long-term average of 544 mm with percentage deviation from the mean only around 10%. The average rainfall for the last 31 years starting around 1970 was about 482 mm. In about 70% of these years, annual rainfall was below the 51-year average of 544 mm with percentage deviation from the mean reaching 50% in some cases (e.g. 1987) (Figure 2). The average rainfall loss between the two periods is around 154 mm. A trend of declining rainfall over the last three decades is therefore evident (Figures 1 & 2). These data show that analysis based on the records of the most recent 30 years is more reliable for characterizing the current rainfall patterns of the study zone (O. Badini, 2001). Therefore, we will use the period (1970-2000) for the assessment of agro-climate in the study site and possibly elsewhere in the region.

b) Long-term Rainfall Variability and Probability Analysis

As shown in the previous section, limiting water availability is one of the main constraints to rainfed crop production in Madiama and the region. But even more critical for agriculture than the actual amount of rainfall or change of seasons is rainfall variability. The mean annual rainfall patterns show a large standard deviation and a high coefficient of variation (CV). For the last 31 years, the mean annual rainfall of 482 mm has a Standard Deviation (variance) of 140 mm and a Coefficient of Variation (CV) of 29 per cent. Annual rainfall probabilities in years out of 10 are plotted in Figure 3. For example, there is a chance of obtaining 885 mm in the area in only 1 year out of 10. In 4 years out of 10, the area is likely to receive only 486 mm per year. In the probability analysis of the monthly rainfall data for the last 31 years in Djenné-Madiama area (Figure 4), rainfall in June can be expected to be at least 12 mm 9 years out of 10 and 83 mm only 1 year out of 10. Rainfall in May and October is unlikely 7 years out 10. This confirms the duration of the season to 3 or 4 months.

Dekadal (every 10-day period) rainfall reliability is plotted in Figure 5. When the median (2 out of 4 years or 50%) rainfall exceeds PET, crops will not suffer water stress. This corresponds for example, to the period from July 29 to September 1 in Madiama area. If the lower quartile (rainfall exceeded in 3 out of 4 years or 75%) falls below 0.5*PET, crops will probably suffer if they are at full leaf canopy or at a sensitive stage of growth. This corresponds to the period after the first decade of September for Madiama. Upper quartile (in 1 out of 4 years or 25%) values greatly in excess of 2*PET indicate the possibility of flooding in lowland sites, as well as water logging and accelerated soil erosion on upland sites. Fungal diseases or spoilage of ripening crops may also occur at times of excessive rainfall (Mutsaers and al., 1997).

c) Applications

Knowledge of long-term rainfall estimates in a given geographical region enables the development of suitable strategies for agricultural planning and implementation (Sivakumar et al., 1984). Agronomists and agricultural engineers to plan water management for crop production and design water collection and storage systems often use frequency analysis of rainfall records. The idea is that the past gives a clue about what to expect in the future.

1.2. Seasonal Rainfall Predictions to Guide Farm Decisions

Development of a region for agriculture, and of individual farms in a region, is in essence a one-time activity, which must consider all the long-term variability in climate such as presented above. However, producing a crop on a certain field in the current rainfall season raises a host of different considerations. More precise information about expected rainfall would be helpful to the farmer at the start of the season and in the early part of the season when basic decisions are being made about how to maximize production and returns per unit of rainfall in the approaching season. The potential for predictability of rainfall amounts and duration based on the rainfall onset dates of the coming season such as proposed by the "response farming" approach (Stewart, 1988) has been evaluated in the present study.

a) <u>Analysis of Seasonal Rainfall Behavior</u>

The rainfall amounts and duration relationships to onset dates have been evaluated in Madiama. The analysis of the last 31 years (1970-2000) of the rainfall records in the Madiama area shows that rainy period duration has a strong correlation (R Square = 0.68) with total rain (Figure 6). The same strong relationship (R Square of 0.76) is noticed between rain duration and date of onset (Figure 7). It is clear that the range of duration of rainfall as well as the expected rainfall amounts, both diminish with each day onset is delayed. Based on the median onset date of June 26, two groupings of onset dates have been identified in Figure 7. One representing "early onset" seasons (16 years) with onset dates before June 26, and the other "late onset" years (15 years) with onset dates after June 26.

Looking at the entire 31-year record (Table 1.1) there is a great range of variability. It shows that onset may occur as early as June 6 or as late as July 30, a span of 55 days. As well, rainfall amounts could vary from 274 mm to 801 mm and season duration may vary from 60 days to 140 days. This represents the advisors and farmer's dilemma when information is lacking as to the significance of the date of onset. It is impossible or near impossible to select crops and cultivars with optimal or near-optimal maturities with such a great range of uncertainty. However, if we divide the Madiama rainfall record on the basis of whether onset occurs by June 26 or after, major differences are revealed in all the season characteristics of interest to the farming community and meaningful recommendations that matter to the people can be implemented. Looking at Table 1.2, the 2 groupings differ in 2 essential features: First, we see that the median rainfall in early season is higher (529 mm), while that of late season is very low (432.5 mm). For the farmer this means emphasis on different crops, different input levels and many other possible measures. Also, we see that the median season duration is much longer (105 days) in early seasons and much shorter (74 days) in late seasons. This again calls for emphasis on different crops and cultivars with different maturity dates.

b) *<u>Applications</u>*

For the farmer, determining that a season at hand would be part of early or late onset years based on when the rain starts, means emphasis on different crops and different levels of inputs. It means different land preparation, different tillage practices or different plant populations. Traditional farmers in much of the Sahelian zone are aware of these relationships, but with the changing world they cannot keep pace with decreasing rainfall. Tradition and limited personal experience and memory are not match for long term weather records and use of computerized analyses such as allowed here. An example of the evaluation and use of such technology is given in the next section.

2. Simulation Modeling and Agroclimatic Assessment

Simulation modeling is evaluated here as a tool that can contribute to the generation of biophysical agroclimatic indicators of the suitability of crops and management technologies that could be used in a recommendation package for years of early or late onset dates of rainfall. The outputs from the soil water budget and crop production modeling were used either singly or in combination to compute the following biophysical indicators: (1) Crop Average Water Stress Index (AWSI); (2) Crop Yields and (3) Overall Stress Index (OSI). Relationships between these indicators and onset dates have been established to evaluate their potential in screening appropriate technologies. Also, These biophysical indicators have been mapped to visually show their spatial distribution and their classes as a function of soil types. Differences are most seen by looking at the maps' legends.

2.1. Crop Average Water Stress Index relationships to onset dates and crop yields

The Crop Water Stress Index (AWSI) was computed to allow better insights in terms of understanding the relationships between crop, weather and soil in the study zone. It is used as an indicator of the plant response to environmental conditions and could help in the choice of crops or soils best suitable to given conditions. Figures 8a and 8b show maps of water stress index throughout the commune. Overall values for water stress in the study zone ranged from 0.04 to 0.6 as a function of soil type and onset dates of rains. A value of 0 represents no stress (optimum growth condition for a crop in regard to water limitation) and a value of 1 represents very high stress level. As expected, early onset dates with higher amounts of rainfall have lower stress levels compared to late onset dates regardless of soil type and input levels (see maps' legends). Overall, AWSI increased with delay in rain onset and with increase in nitrogen level when plant requirement for water is higher.

2.2. Yields relationships to onset dates and nitrogen (N) inputs

Figures 9a and 9b show the yields relationships to onset date, N inputs and soil water limitations. Soils with higher water holding capacity such as Ci and Ca have higher yields levels regardless of input levels or date of rain onset. Shallow soils such as Vi (< 40 cm deep) have shown total crop failure (less than 100 kg/ha) regardless of input level or onset date. Overall, yields decreased with delayed rain onset regardless of input levels. But fertilization level is found to have a higher impact on yield increase in early onset years than in late onset years.

To better illustrate the importance of onset dates, probabilities of simulated millet yields categories were presented in Table 2. Considering the case of millet yield with no nitrogen input, overall odds are almost evenly split between a good crop (36%), a fair crop (27%) and a poor to failure crop (37%). The same observation is true even in case of fertilization. But a radical shift occurs between early and late onset seasons. Early seasons have a 56% probability of a good crop with only 19% chance of failure. With late seasons there is only 14% of chance of good crop against 57% chance of crop failure. These categories are only illustrative but the analysis made possible by the simulation modeling shows that less water demanding crops should be substituted in late seasons.

2.3. *Overall Stress Index (OSI) relationships to onset dates, nitrogen inputs and crop yields*

In the present work the OSI is considered as a biophysical indicator of crop yield potential permitted by different soils under low and optimum nitrogen input levels. It integrates most of the biophysical limitations in crop growth including light, temperature, water and nitrogen. A value of 0 indicates no stress and a value of 1 is maximum stress. The OSI allows one to determine the best soil with less risk of crop failure associated in years of early or late onset dates.

Overall, OSI in early onset years is lower (ranging from 0.08 to 0.09) than in late onset years (0.05 to 0.30) (Figures 10a and 10b). In early onset years, average water holding soils such as t1 and t2 showed the lowest risk with OSI values of 0.08 and 0.09 (Fig. 10b). Soils with high water holding capacity such as Ci and Ca are not suited to millet in early onset years in the present case because certainly of water logging, higher humidity, lower radiation and temperatures that will contribute to delay crop development and growth. However, in late onset years the higher OSI levels are noticed for average water holding soils such as t1 and t2 (Fig. 10a). Overall, OSI and riskiness levels increased with delay in rain onset. Late onset years have higher OSI levels. But soil type needs to be considered for optimizing management dependent on late or early years.

APPLICATIONS

With the help of soils, weather, crops and management databases in association with cropping systems simulation models and GIS, we could offer better insights through long term screening and analysis about what crop, technology or cropping system could fit better to the environment at hand. Another major application will be to provide plant breeders with a better representation of the situation actually faced by farmers for whom breeding programs are undertaken. Also, extrapolation of findings to other similar environments can be facilitated.

CONCLUSIONS

The present contribution deals with rainfall analysis, soil-water and crop production simulation modeling useful for the suitability assessment of crops and management to be recommended in a response farming approach.

Rainfall data and simulated soil water and crop yields from the study site are used to illustrate how this approach might work for farmers in the Madiama region and beyond.
For this illustration, analysis of the last 31-year rainfall of the study region has shown the high variability and low reliability of the weather. However, strong relationships exist between the time of rain onset and the rainfall duration and expectations as shown in previous studies. The earlier the onset, the higher the expectations for duration and total rain. Also, relationships between onset date, agroclimatic indices (water stress and overall stress) as well as crop yields have been evaluated and are satisfactory. Water stress indices always increased with delay in rain onset and yield decreased with late onset regardless of fertilization levels.
Although, some farmers in the region are well aware of the implications of late onset and do respond to it with some measures to insure survival level production, they may be less aware of the good implications of an early onset of rains and how they might benefit from

increased input levels and other measures in these years. The information generated from the present study shows that farmers might for example better profit from increased inputs levels in early onset years and that could mean improving subsistence level production to economic level production.

As might be, the relationships and information determined in the present work are illustrative and represent a work in progress but their interest is twofold: 1) to show that they may be a real benefit to be gained from weather analysis integrated to simulation modeling in a response farming approach and 2) to suggest the establishment of a research activity based on the response farming approach where flexible recommendations will be evaluated and applied in the study region and beyond.

Table 1.1: Range of Values (Variability) of cropping season rainfall characteristics, including date of onset, rainfall amount and duration. Presented first for all years, then for early onset versus late onset years.

No. of years	Onset period	Onset date	Prediction date	Amount (mm)	Duration (days)
		---------------------***Range of Values***-------------------------			
31	All	June 6-July 30	N/A	274-801	61-40
16	Early	June 2-June 26	Onset to June 26	406-801	93-140
15	Late	June 28-July 30	June 27 on	274-617	61-98

Table 1.2. Median Values of cropping season rainfall characteristics, including date of onset, rainfall amount and duration. Presented first for all years, then for early onset versus late onset years.

No. of years	Onset period	Onset date	Prediction date	Amount (mm)	Duration (days)
		---------------------***Median Values***------------------------			
31	All	June 27	N/A	502.5	98
16	Early	June 11	Onset to June 26	529	105
15	Late	July 8	June 27 on	432.5	74

Table 2: Example of Simulated Millet Yields Probabilities with no Nitrogen and (Optimum N) inputs in Early and Late Onset Years

			EXPECTED YIELDS CATEGORIES		
Onset period	No of years	Onset date	Good Crop (> 800 kg/ha)	Fair Crop (400-800 kg/ha)	Poor/failure Crop (< 400 kg/ha)
			--------------**Probabilities (%)**--------------		
All	30	June 6-July 30	36 (40)	27 (27)	37 (33)
Early	16	June 2-June 26	56 (50)	25 (31)	19 (19)
Late	14	June 28-July 30	14 (28)	29 (21)	57 (51)

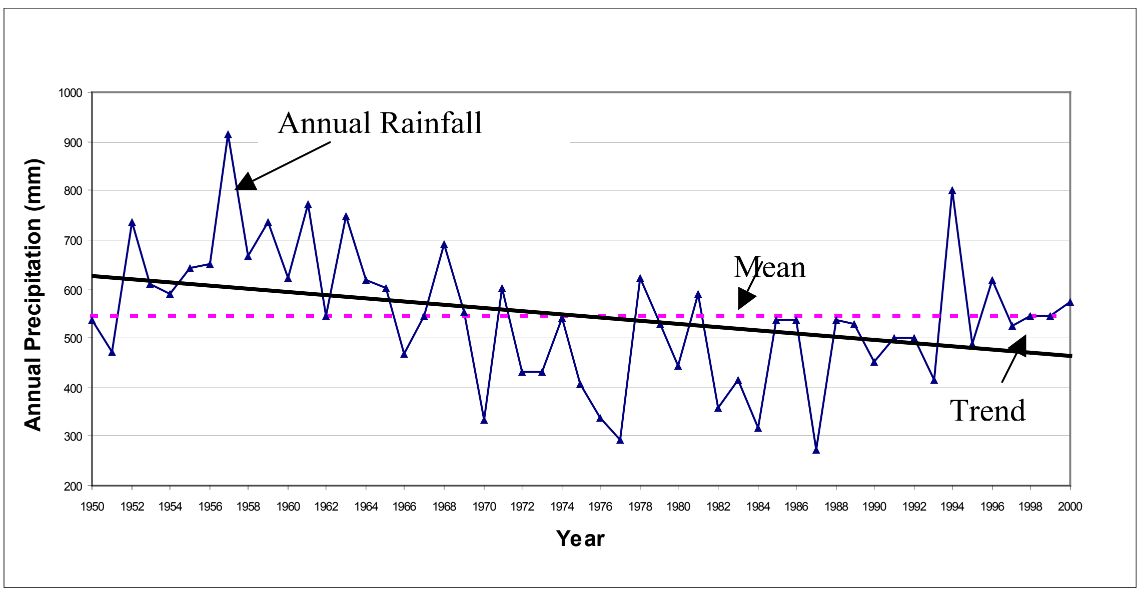

Figure 1: Precipitation Distribution, Mean and Trend from 1950 to 2000 in Djenné-Madiama

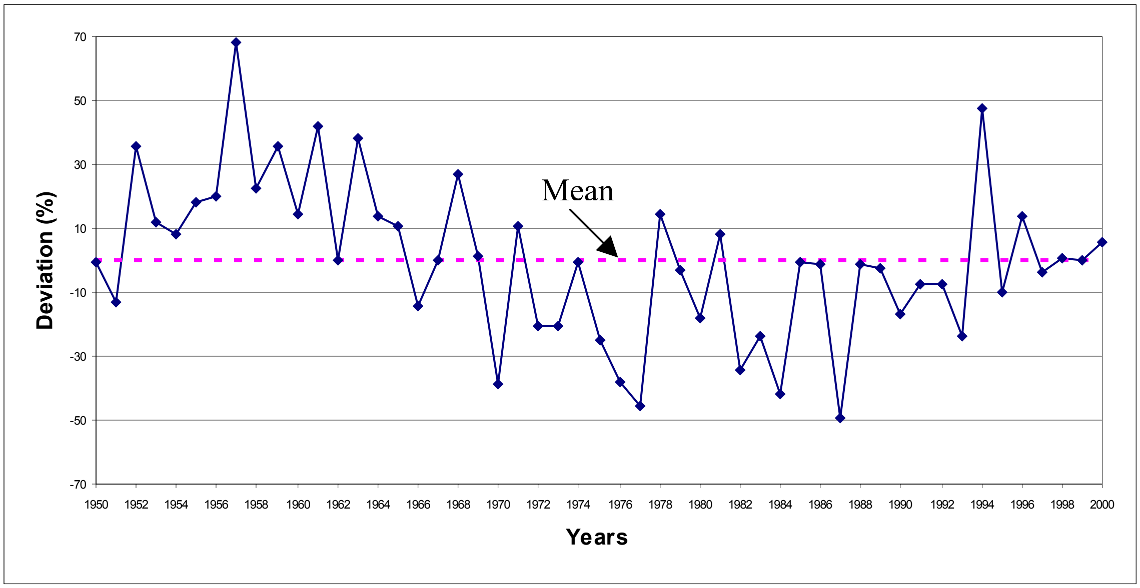

Figure 2: Rainfall Variability as a Percentage of Deviation from the long-term mean (544 mm) for the Study Area

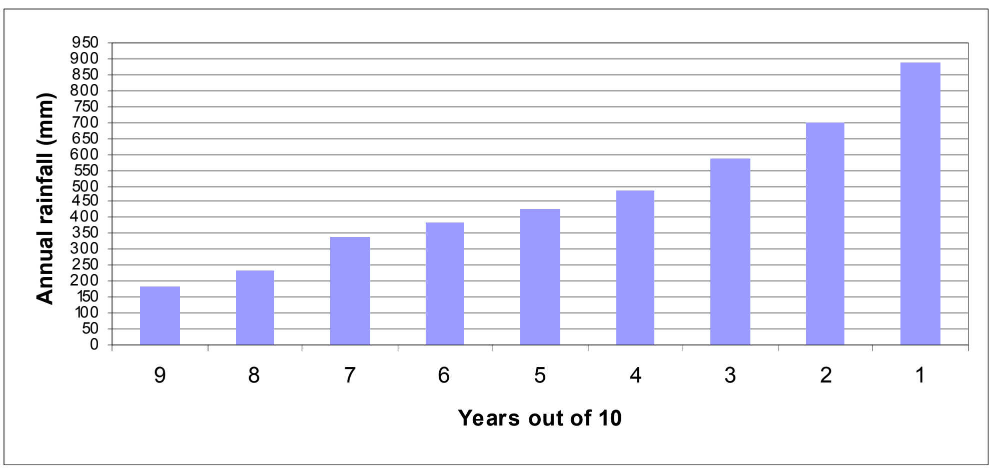

Figure 3: Annual Rain Probabilities in years out of 10

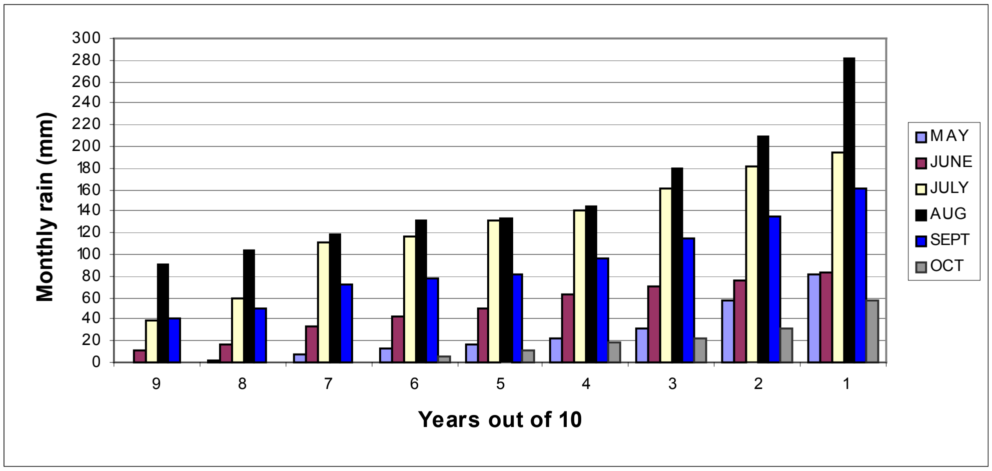

Figure 4: Monthly Rain Probabilities in years out of 10

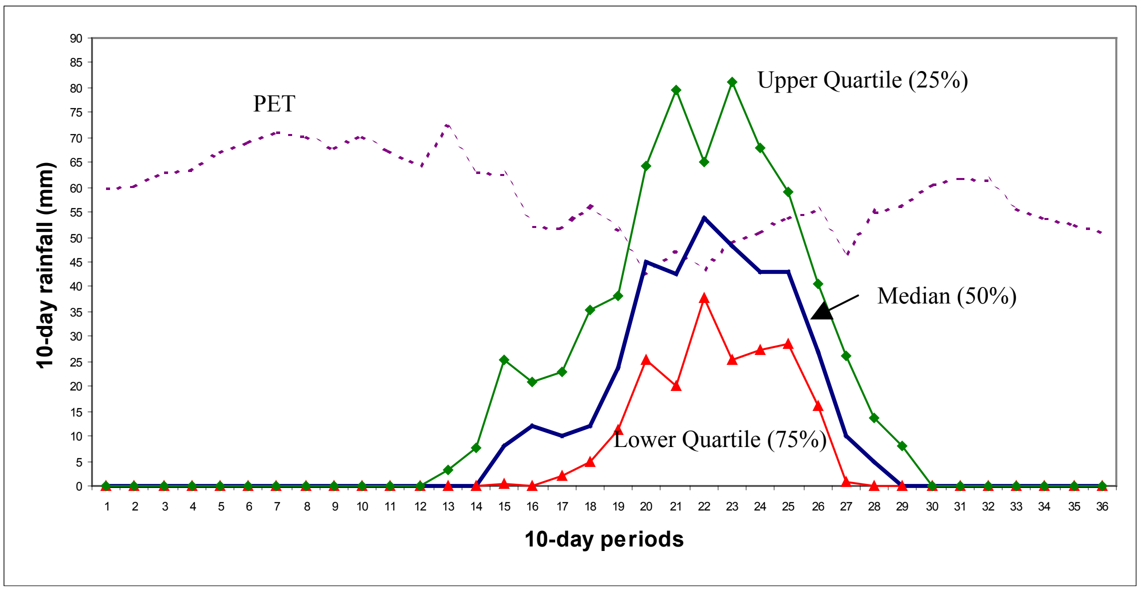

Figure 5: Confidence Interval for 10-day total rainfall and Potential Evapotranspiration (PET)

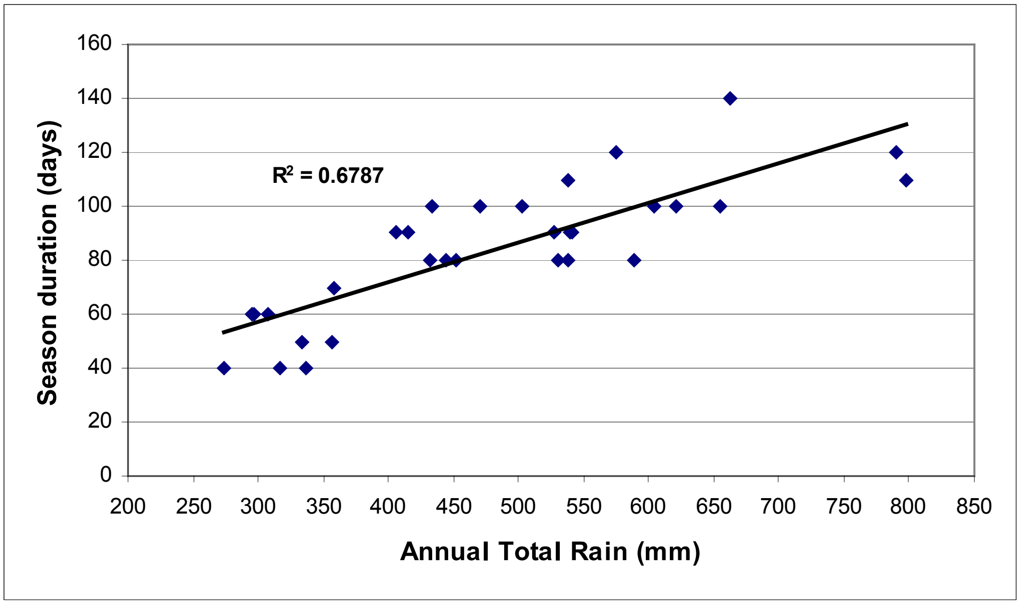

Figure 6. Length of Growing Season vs. Annual Total Rain

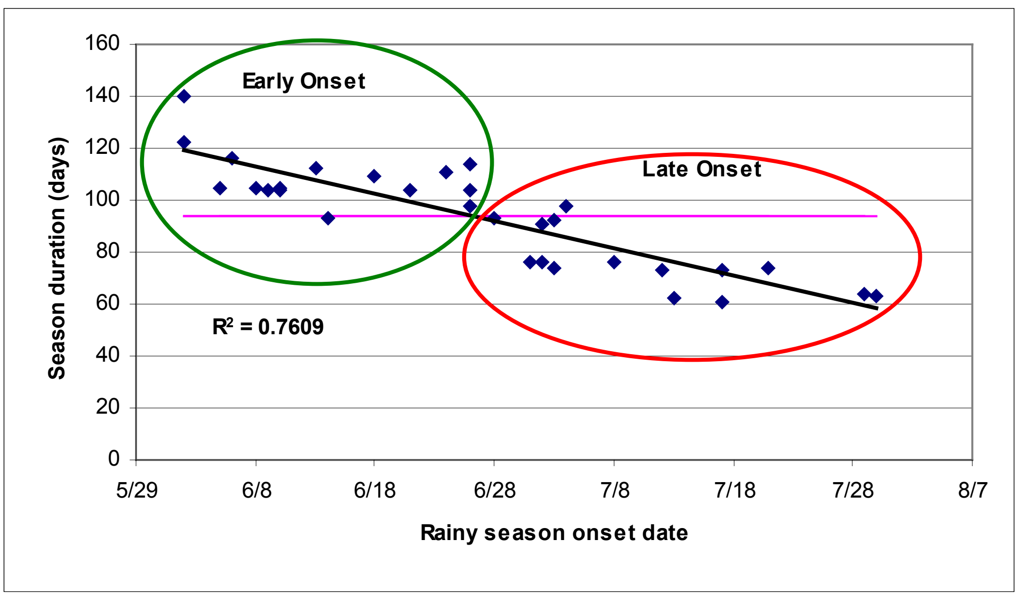

Figure 7: Rainy Season onset date vs. Season duration

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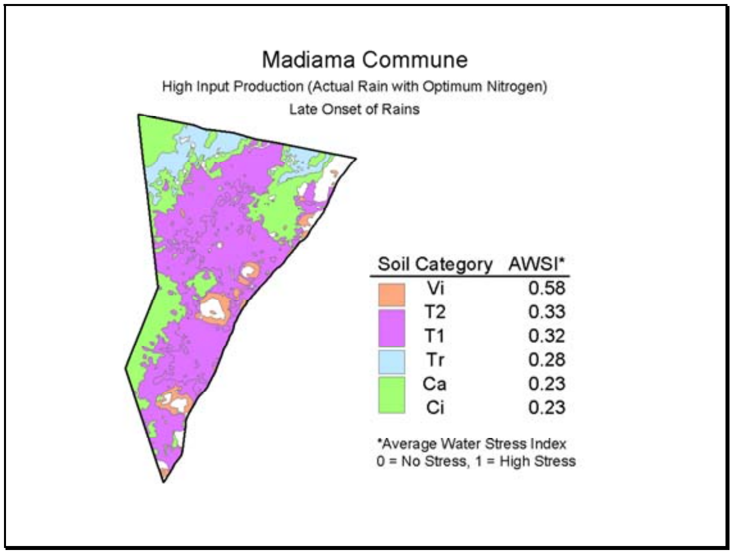
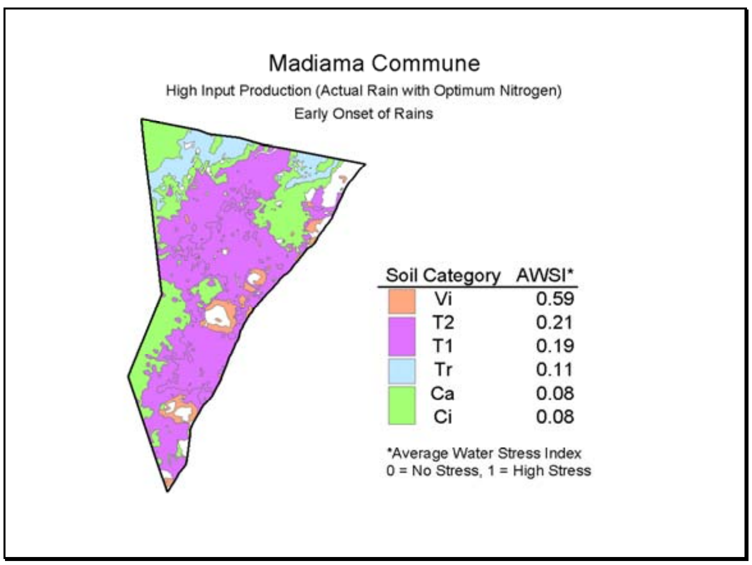
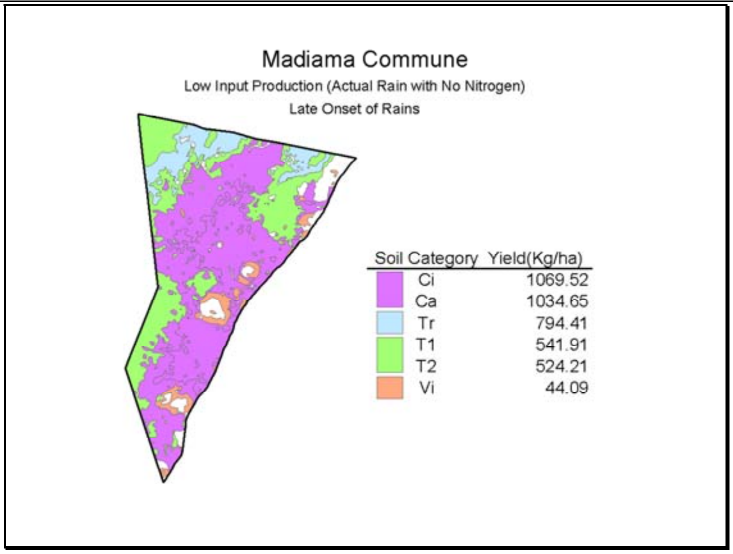


(a)



(b)

Figure 8: Average Water Stress Index vs. Onset dates



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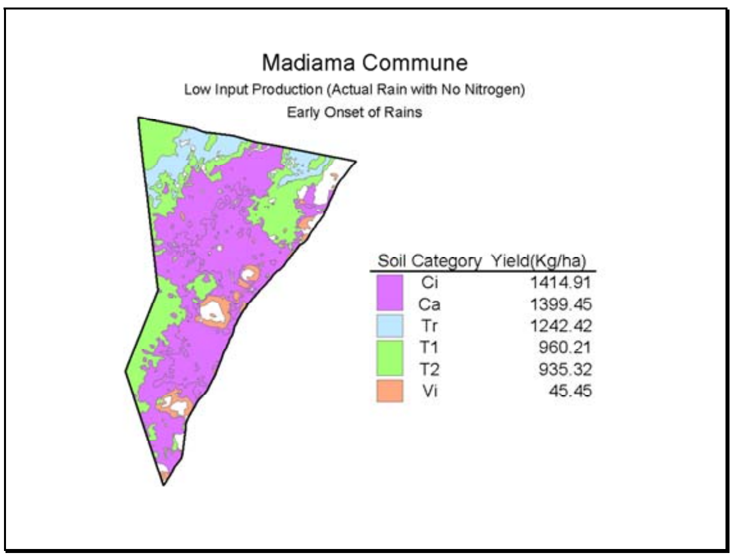

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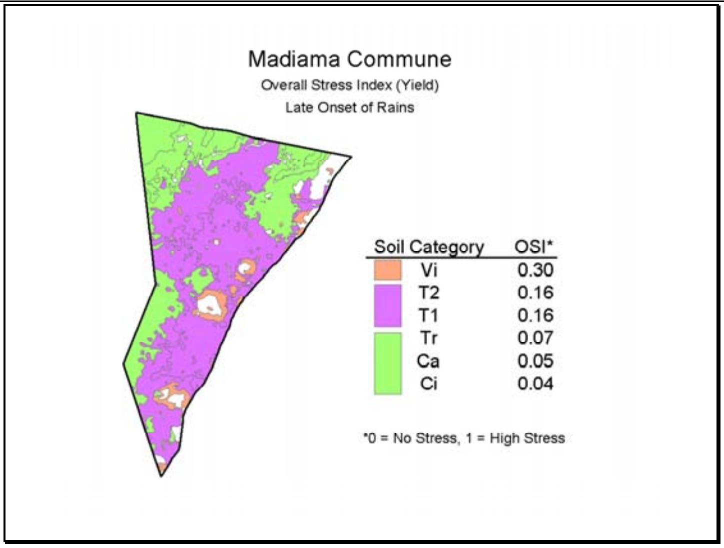
Figure 9: Simulated Yields vs. Onset date



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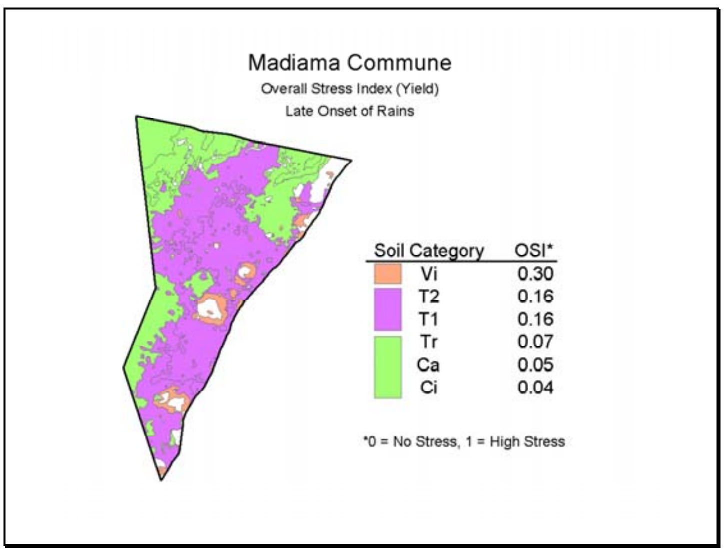

(b)

Figure 10: Overall Stress Index (OSI) vs. Onset date

Economic Interdependence Among Socio-Economic Groups in Madiama Commune of the Niger Delta of Mali[1]

Charlene Brewster[2], Daniel Kaboré[3], Michael Bertelsen[4] and Peter Wyeth[5]

ABSTRACT

One aim of the SANREM West Africa Project is to identify the linkages among socio-economic groups in the Madiama commune of northern Mali. The results from compiling a Social Accounting Matrix (SAM) were reported earlier. These results clearly demonstrated that transhumants are the least favored of the occupational groups, so that any development interventions should address this group separately. In this paper, the SAM is disaggregated further and decomposed multipliers computed. Three groups of decomposed multipliers are computed – direct effect, open loop and closed loop multipliers. The process of decomposition separates the impact of interactions among production activities from that due to interactions among socio-economic groups. These latter interdependencies are important to understand in a commune where rivalry among groups for resources is strong. Analysis of the multipliers and the pattern of primary commodity sales and microenterprise activity reinforces earlier conclusions about the importance of the livestock sub-sectors and the fragile position of the transhumant pastoralists.

INTRODUCTION

In the Niger Delta Region of Mali there is a long history of shared resource use among farmers, fishermen, and pastoralists. Like most areas of sub-Saharan Africa, the region is characterized by a combination of growing population pressure, low and declining agricultural productivity and low soil fertility. With increasing natural resource depletion, the area has witnessed heightened conflict between affected groups over access to cropping and grazing lands and water. In the Madiama Commune area of Mali, the major river (the Bani) supplies less water and cropping activities suffer each year because of decreasing rainfall in the area. Crop yields have declined significantly over the years, and farmers have expanded cultivated lands to compensate for yield losses. As the pressure on natural resources increases, so too does the potential for greater conflict as families try to achieve the objectives of better health, food security and education for their members in the face of poverty. Poverty itself is one of the greatest contributors to resource degradation since the poor may discount the future more heavily, thus solutions to the resource degradation problem must encompass poverty alleviation as a major goal.

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Economic growth within the commune is one way of relieving the pressure on natural resources if such growth does not preclude the alternatives of future generations. If it is to be sustainable, economic growth must lead to sustainable use of natural resources.

Developing an economic growth strategy requires a comprehensive understanding of the linkages within the local economies. The selection of economic sectors most likely to contribute to sustainable economic growth in the region is not an easy task, but must be done carefully if targeted groups of natural resource users are to be positively impacted. Four groups of natural resource users have evolved over time within the region.

(a) Farmers: for this group of individuals, agricultural production systems are their major activities.

(b) Agro-pastoralists: these individuals rear animals in conjunction with farming activities, as part of a risk reduction strategy.

(c) Sedentary pastoralists: this group of individuals has herds of larger size than agro-pastoralists. Their animals graze both within and outside of the commune, however the household is sedentary, and in addition these individuals usually carry out some type of farming activities

(d) Transhumant pastoralists: these individuals travel inside and outside of the commune seeking water and pasture for their animals. Generally, they move around the Niger River Delta region's water sources during the dry season and then move south or east during the rainy season.

It is impossible to design and implement pro-growth policies that will positively impact natural resource users unless linkages within the local economies are properly understood. The objective of this study is to model these linkages and analyze the potential impact of targeted growth strategies on different groups of natural resource users. An extensive data set collected in the Madiama Commune area is used to develop a Social Accounting Matrix (SAM) in order to (a) analyze the linkages among stakeholders and institutions (b) trace the path through which growth strategies may affect different sectors and institutions within the commune. Preliminary results of this analysis have been presented (Kaboré et al. 2000), and this paper presents new results on the process of multiplier decomposition. The process of multiplier decomposition allows decision makers to trace how growth in one sector or industry will impact the other industries, sectors, and groups of natural resource users within the commune.

METHODOLOGIES

Methods of Data Collection

The commune, the newly created and lowest decentralized administrative unit in Mali, was chosen as a relevant geographical survey unit and the Madiama commune was selected in consultation with NGO (Non Government Organization) partners and IER (*Institut d'Economie Rurale*) collaborators. Focusing at this level will allow commune level decision-makers to directly use the results of the study. This selection of the study area was made during a workshop in Bamako, Mali and a two-week Participatory Landscape/Lifescape Appraisal

(PLLA) carried out in February 1999 in Madiama commune gave preliminary data that were used to select study villages for follow-up formal production and income-expenditure structural surveys. In depth structural surveys were carried out in February-March and in September 1999.

Information from the PLLA as well as secondary data (Mali 1996 Census data) was used to select study villages. Five of the ten villages in the study area were selected: Madiama, the headquarters of the commune; Nerokoro, a pastoralist village; Promani, a village of sedentary and transhumant pastoralists and farmers; Tombonkan, a farmers' village; and Tatia-Nouna, a village of farmers and agro-pastoralists. The list of the households in the commune was obtained for each village from the 1996 census data available from government offices (Sofara, 1996). The sample size was 120 households randomly selected representing about 10% of the commune households in 1996. The distribution of the four groups of stakeholders in the sample is presented in Table 1.

A meeting was held in each village with the farmers/herders in order to explain the objectives of the study and to encourage them to be patient and open to the questions. The active participation of a Fulani community leader from Nerekoro was particularly helpful in soliciting the participation of the transhumant pastoralists while the Chief of Tatia-Nouna was very supportive in gaining farmer confidence. Individuals to sample were randomly selected from the village list and the stakeholder group that they belonged to was determined by the consensus at the meeting.

Table 1: Sample distribution by activity and village, Madiama commune Mopti region, Mali, 1999

Village	**Group by Main Activity**				**Total**
	Farmers	**Agro-pastoralists**	***Pastoralists***		
			Sedentary	**Transhumant**	
Madiama	12	20	0	0	32
Promani	08	05	10	0	23
Tombonkan	09	01	0	0	10
Tatia-Nouna	14	06	04	0	24
Nerekoro	0	01	09	21	31
TOTAL	43 (36)	33 (27)	23 (19)	21 (18)	120 (100)

Sample size as a percentage of total population is expressed in parentheses

Two types of data were collected. The first group of data was related to household characteristics, production and consumption, factors exchanged (labor, equipment, land, money). Origin and source of factors exchanged were also recorded. The questionnaire was administered by four enumerators and two supervisors: a researcher from the *Institut d'Economie Rurale (I.E.R)* of Mopti and the author, a graduate student from Virginia Polytechnic Institute and State university. A two-day training session for both enumerators and the IER researcher was conducted in Madiama in order to explain the objectives of the study, the SAM approach and the requirements of this kind of survey. The survey conducted in February-March 1999 took 3-4 hours for each respondent and was scheduled with a break after two hours or so, by the time of the Muslim prayer or lunchtime. Each enumerator was assigned to survey a maximum of two households per day in order to avoid weariness and therefore preserve data quality.

The second group of data was collected on microenterprise activities in the commune that are income generating activities such as food processing, handcrafts, retail trade, livestock trading, cereal trading and so forth. This data was collected in September 1999 on a sub-sample of 60 households drawn from the larger sample of 120 households. A pre-test was implemented with a few respondents in order to (a) correct/improve the questionnaire and (b) give enumerators survey experience. The training, the pre-test and the questionnaire improvement took one week (Kabore et al., 2000).

THE SAM FRAMEWORK AND MULTIPLIER DECOMPOSITION

The SAM Model

A Social Accounting Matrix (SAM) model was developed to meet the objectives of the study. The SAM model is a modified input/output model that shows the flow of income and expenditure among production activities among stakeholders. It is a very flexible and powerful tool that can be used to analyze economies in diverse social and cultural settings (Taylor et al. 1996). It has been used in analysis of village economies (Subramanian, 1988) as well as for nationwide studies (Dorosh et al. 1991, Arndt et al. 1998; Pradham et al. 1999). Given its flexibility, the SAM can also be developed to address specific topics such as environmental issues (see Miller et al. 1985) or migration (Adelman et al. 1988).

The SAM is organized as an accounting matrix of modeler-selected endogenous and exogenous sectors' inflows and outflows. It is based on the assumption that production activities are endogenous and demand-driven. Endogenous accounts are those for which changes in the level of expenditure directly follow any changes in income. The endogenous accounts typically include (i) production activities (the input-output sub-matrix), (ii) factors (labor) and (iii) institutions (households and firms). Exogenous accounts are typically those for which we assume that expenditures are set independently of income. These consist of (i) government, (ii) capital and (iii) the rest of the world. By convention, receipts (incoming value added) to a sector are listed in the rows while expenditures (outgoing) appear in the columns (see Table 2). Table 2 contains transformation matrices involving the endogenous accounts: $\mathbf{A}_{11}$ gives the intermediate input requirements i.e. the input-output transaction matrix; $\mathbf{A}_{13}$ reflects the expenditure pattern of the institutions (households) for different commodities they consume from the production sector. $\mathbf{A}_{21}$ dispatches the value added generated by production activities by factor while $\mathbf{A}_{32}$ captures the income distribution to the various institutions. $\mathbf{A}_{33}$ maps the income transfers within and among households (institutions). The row totals received by endogenous accounts are given by $\mathbf{y}_n$ which consist of (a) expenditures by endogenous accounts $(\mathbf{A}_{nn})$ summed up as $\mathbf{n}$ and (b) expenditures by the exogenous accounts recorded as $\mathbf{A}_{nx}$ and summed up as $\mathbf{x}$ and referred to as injections. Finally $\mathbf{y}_n = \mathbf{n} + \mathbf{x}$ and similarly, income received by exogenous accounts $\mathbf{y}_x$ is $\mathbf{y}_x = \mathbf{l} + \mathbf{t}$. Since Table 2 is a SAM, rows and columns should balance; that is: $\mathbf{y}_n = \mathbf{y}_n'$ and $\mathbf{y}_x = \mathbf{y}_x'$ where $\mathbf{y}_n'$ and $\mathbf{y}_x'$ are column analogs of row sums $\mathbf{y}_n$ and $\mathbf{y}_x$ respectively.

Table 2: Simplified SAM Structure

			EXPENDITURES (Outflows)				Totals
			ENDOGENOUS			EXOGENOUS	
			Production	Factors	Institutions	Sum of other Accounts	
RECEPTS (Inflows)	ENDOGENOUS	Production	$\mathbf{A}_{11}$	--	$\mathbf{A}_{13}$	$\mathbf{x}_1$	$\mathbf{y}_1$
		Factors	$\mathbf{A}_{21}$	--	--	$\mathbf{x}_2$	$\mathbf{y}_2$
		Institutions	--	$\mathbf{A}_{32}$	$\mathbf{A}_{33}$	$\mathbf{x}_3$	$\mathbf{y}_3$
	EXOGENOUS	Sum of other Accounts	$\mathbf{l}_1'$	$\mathbf{l}_2'$	$\mathbf{l}_3'$	$\mathbf{t}$	$\mathbf{y}_x$
TOTALS			$\mathbf{y}_1'$	$\mathbf{y}_2'$	$\mathbf{y}_3'$	$\mathbf{y}_x$	

Exogenous variables might include, for example, government input subsidies or taxes. Shocks introduced into the commune economy as a result of changes in these variables produce changes in the circular flows of resources among sectors within the commune. The magnitudes of these impacts (measured by multipliers) depend upon the strength of the linkages between the sectors. Similarly, the impact (and multipliers) of a decision made within the Madiama commune will be related to endogenous variables such as changing land distribution among sectors or changing transhumance scheduling through commune taxation of grazing lands. The natural resource management decision-makers of the commune will have the authority to make decisions about such variables in the future. The multipliers provide important information to commune level decision-makers on the prospects for, and differential impacts of, economic growth on the various sectors. This has direct implications for who benefits and loses from policy changes and, by extension, how conflicting sectors benefit and how they might accordingly react to changes. The development of a SAM is a useful first step to begin such analyses because its flexible structure permits disaggregation into the relevant classes of interest (farmers, agro-pastoralists, sedentary pastoralists and transhumant pastoralists). Earlier papers (Kabore et al. 2000) presented preliminary results of this study. These studies indicated that agropastoralists as a group will benefit most from increases in activities and income, while farmers, sedentary and transhumant pastoralists have respectively declining shares of these impacts.

Multiplier Decomposition

Analysis of the magnitude of decomposed multipliers allows decision makers to fully trace the effects of interventions in one sector or industry. They provide decision-makers (at the commune-level) with information about the differential impacts of economic growth on various sectors within the commune. Three types of multipliers are calculated using the method developed by Pyatt and Round (1979) and illustrated by Holland and Wyeth (1993).

(a) Direct Effects Multipliers (transfer effects): Transfer effects capture the direct effects that are the result of interactions within each category of accounts e.g. intersectoral input-output elements. An example of such a shock could be an increase in demand for a commodity, e.g. small ruminants. The direct effect multiplier demonstrates how this shock is transmitted through the other production activities in the commune.

(b) Indirect or Open Loop Multipliers: When one sector is affected by an exogenous shock, these multipliers show how the impacts are transmitted to the other categories of accounts, for example from production categories to factor incomes. These are one-way effects, and any impacts on the originating sector are excluded. For example, indirect multipliers may illustrate the impact of changes in production activities on factors such as labor, or on the different groups of natural resource users within the commune.

(c) Closed Loop Multipliers: This group of multipliers shows the full circular effect of a shock. They demonstrate how a shock to a sector travels outwards to other sectors and then back to the original point of origin.

ECONOMIC INTERDEPENDENCIES WITHIN THE COMMUNE

Primary Sales and Microenterprise Activities

When describing the economic interactions within the commune, two sectors can be distinguished. The tradable sector, as the name suggests, consists of goods and services that are traded with regions external to the commune. The price of tradable goods is determined outside of the commune where there is a larger effective demand for these commodities. The commune can sell all of its production at this price, however as production rises, the cost of producing additional units of production also rises (upward sloping supply curve). If these costs rise above the market price, then the commune will no longer be able to sell this commodity to the external world without sustaining economic losses. Growth strategies aimed at expanding the tradable sub-sector must focus therefore on improving technologies and management systems so that production costs are lowered. The non-tradable sector consists of goods and services that are not traded outside the wider area, though there may be some trade within the commune itself. In Madiama, the non-tradable goods include meat, fish, millet, milk, sorghum, and legumes. Labor and manure are non-tradable inputs, because their use is confined to the commune. Expansion of the non-tradable sector is constrained by low levels of demand, rather than problems of supply. Much more of these goods and services can be provided (their supply is elastic), but the level of demand does not justify this.

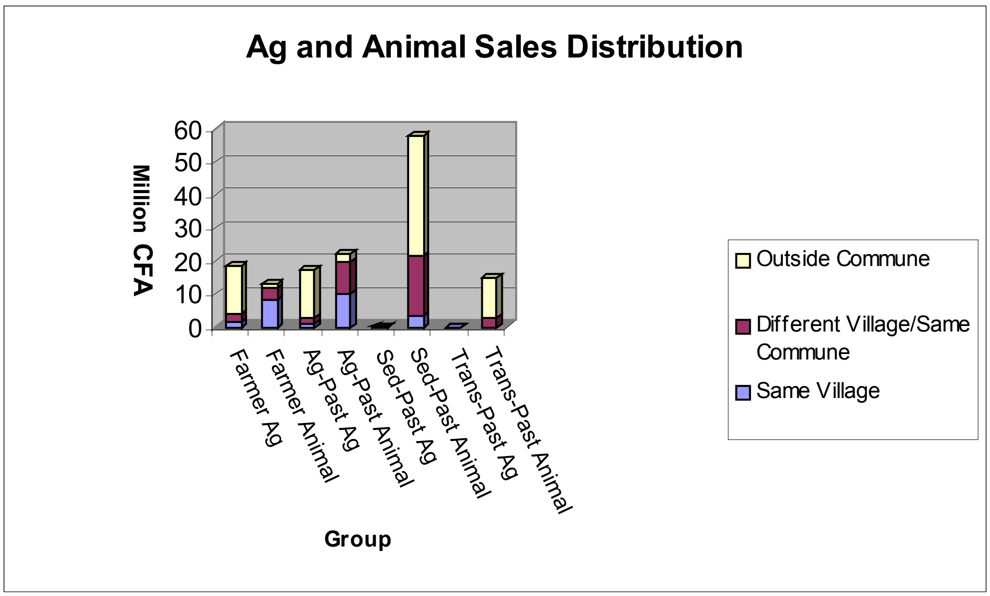

Figure 1: Sales of Primary Crop and Animal Products

An examination of the sales data for primary agricultural products reveals the importance of exports in the trade of primary livestock products (Figure 1). The livestock trade is particularly important to sedentary pastoralists, and for this group over 50% of sales is to areas outside of the commune. The major tradable crop products include rice and vegetable crops, primarily gumbo (okra).

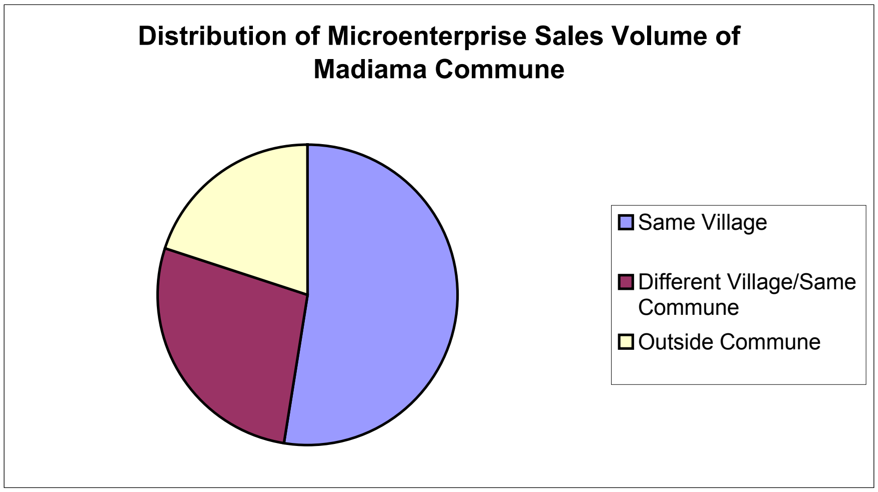

Figure 2: Distribution of Microenterprise Sales Volume in Madiama Commune

Figure 2 describes the pattern of microenterprise activity in the commune. Sales in the tradable sector account for 20% of all microenterprise activity, with sedentary pastoralists accounting for the largest share of activity and transhumants the least (Table 2).

Table 2: Microenterprise Activity for Madiama Commune ('000 CFAF)

Type of Activity	*Farmers*	*Agro-pastoralists*	*Sedentary Pastoralists*	*Transhumants*
Same Village Sales	3025.6	21098.7	24525.9	
Sales within commune – different village	2570.4	4541.0	18132.0	
Sales outside Commune	10710.0	3641.4	2934.5	1299.9
Totals	16306	29281.1	455924.4	1299.9

This pattern of trade suggests a direction for growth strategy. Over the years, development agencies have increasingly looked towards the microenterprise sector as a vehicle for growth. The existence of a tradable microenterprise sector (though relatively small) suggests a starting point. Since much of the Madiama economy revolves around the non-tradable sector, then economic growth strategies should focus on increasing incomes so that demand for non-tradables will increase. One way of increasing incomes is to reduce the supply constraints associated with the tradable sector, so that more commodities and services can be produced and traded. Thus research investments that focus on lowering livestock production costs for example through increased pasture management will be instrumental in raising incomes. The data on primary product sales suggests that any development strategy should focus on the livestock sector. Results of the multiplier analysis also suggest avenues for development work.

RESULTS AND DISCUSSION

The own effect multipliers describe the impacts of a shock in one sector or industry, on the other endogenous sectors. Table 1 illustrates the effects of exogenous increases in demand for specific commodities. Only the impacts on the sector that receives the shock are shown, since impacts on other sectors are small. The largest multipliers are those associated with rice and livestock. Interpretation of these multipliers is straightforward, for example an increase in rice exports of one million CFAF, then interindustry transactions alone would induce increases in output of 1.17 million CFAF. Large increases in output would also be induced by increases in demand (or by investment) in the livestock and livestock microenterprise sectors.

Table 3: Selected Own Effect Multipliers for Madiama Commune

Introduction of shock	***Sector of Impact***	***Own Effect Multiplier***
Rice	Rice	1.17
Small Ruminants Microenterprise	Small ruminants Small Ruminants Microenterprise	0.16 1.17
Large Ruminants Microenterprise	Large Ruminants Large Ruminants Microenterprise	0.19 1.17
Poultry microenterprise	Poultry microenterprise	1.37

Open loop effects are shown in Table 4. This group of multipliers describes the impact of a shock to one sector on other sectors outside of that block. The open loop multipliers in Table 4 demonstrate the impact of exogenous changes on incomes of stakeholders within the commune. For example, a one million F CFAincrease in demand for millet will result in increases in income for farmers of 216,000 CFAF, 355,000 F CFAfor Agropastoralists, 224,000 F CFAfor sedentary pastoralists and 125,000 F CFAfor transhumant pastoralists. It can be seen that in general, the multipliers for transhumant pastoralists are significantly less than those for the other groups of stakeholders. In addition, agropastoralists would benefit the most from increases in commodity demand, followed by sedentary pastoralists, farmers and then transhumants. It is also noteworthy that the open loop multipliers for the natural resources and food products category is large, illustrating the potential for economic growth through sustainable exploitation of natural resources.

Table 4: Selected Open Loop Effects for Madiama Commune

	Millet	***Rice***	***Small Ruminants***	***Large Ruminants***	***Natural Resources & Food Proc.***
Farmers	0.216	0.199	0.230	0.221	0.203
Agropastoralists	0.355	0.340	0.395	0.380	0.269
Sedentary Pastoralists	0.224	0.207	0.238	0.230	0.132
Transhumant	0.125	0.108	0.122	0.117	0.068

Selected closed loop effects are shown in Table 5. These multipliers show how a shock in one sector is transmitted through all the other blocks and back to where it started. The multipliers in Table 5 show how the effects of changes in income of one group, will work through the system and impact incomes of all groups in the commune.

Table 5: Closed Loop Multipliers for Institutions within Madiama Commune.

	Farmers	Agropastoralists	Sedentary Pastoralists	Transhumants
Farmers	1.34	0.34	0.34	0.38
Agropastoralists	0.58	1.58	0.58	0.66
Sedentary Pastoralists	0.35	0.35	1.35	0.40
Transhumant	0.18	0.18	0.18	1.20

These results show that in general transhumants benefit the least from injections of income into the system. This confirms a result identified in earlier work on this model.

CONCLUSIONS

The study illustrated the linkages between socioeconomic groups in the commune. An analysis of production and sales activity demonstrated the relatively closed nature of the commune i.e. the tradable sector is relatively small compared to the non-tradable sector. Impacts from exogenous changes in demand for the commune's agricultural and livestock production, as measured by multipliers, are shared differentially among socioeconomic groups with the transhumant group always benefiting least. This reinforces earlier conclusions that interventions need to specifically target this group. Decomposing multipliers provides decision makers with additional information on the potential impact of measures taken to stimulate economic growth. Direct effect, open loop, and closed loop multipliers enable the tracing of impact information throughout the entire economy.

The analysis has demonstrated the importance of stimulating the tradable sectors within both agriculture and livestock. Interventions stimulating growth in the livestock sector are especially important. Such growth will directly provide the largest impact for all socioeconomic groups, especially the diversified agropastoralist and sedentary pastoralist groups. Growth strategies directed solely toward microenterprise development are possibly misguided: there appears to be little potential to stimulate broader growth within the commune since most microenterprise activities are non-tradable.

Future research should continue to further explore socioeconomic linkages within the commune and their potential to guide further SANREM interventions. More sophisticated analysis, including Computable General Equilibrium (CGE) modeling may provide helpful insight.

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Governance and Natural Resource Management: emerging lessons from ICRAF- SANREM Collaboration in the Philippines[1]

Delia C. Catacutan[2], Dennis P. Garrity[3] and Caroline Duque[4]

ABSTRACT

The concept and practice of governance and natural resource management is emerging as a popular debate in the Philippines, as in many countries in the region. It is now widely accepted that, Local Government Units (LGU) play a critical role in the management of resources within their jurisdiction. This debate is constructed from a combination of people, processes and structures under a diversity of circumstances. Hence, it's pluralistic nature, necessitates participation more widely by various civil society sectors, including the scientific community.

Our collaborative work with SANREM/CRSP is a serious attempt to understand better the methodological, institutional and policy hurdles impinging the success of local natural resource management. The experience begun in Lantapan in phase 1 of SANREM, with the aim to better integrate environmental knowledge in planning and decision-making at the watershed level. SANREM supported an LGU-led planning process for the development of a five-year Municipal Natural Resource Management and Development Plan (NRMDP) of Lantapan. The NRMDP was recognized as a national model for locally-led and research-based NRM planning by the Philippines' National Strategy for Watershed Management (DENR-FMB, 1998). Inspired by the Lantapan experience, a scaling-up process was pursued in four municipalities in northern Bukidnon. The recently completed plans were legitimized with institutional and financial support-- embracing the technological, institutional and policy aspects of resource management.

We concluded that there are socio-political and technical factors affecting the sustainability of local NRM. Four sustainability factors to successful NRM emerged from our study. These are: clear local financial investment, enhanced local technical capacity, sound political culture conducive to NRM, and a supporting National Mandate. However, to ensure that these conditions are met will require a virtual overhaul of programmatic areas of effective governance, as well as, setting a national level policy direction that proactively support the local enforcement of such policies. These factors are in fact, conditions predispose to sustainable NRM at the local level.

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INTRODUCTION

The inextricable link of good governance to local NRM, brought profound challenges,--needing a paradigm shift in the planning, legislative and political processes at the local government level. The Philippines' Local Government Code of 1991 created sweeping changes from centralized government to decentralization—thereby, creating space for an improved local NRM. LGUs however, are stifling its ability to explore the optimum benefits of the Code, as they face the dilemma of the pre-Code influence, and the modernist theorems of politics and governance. The imperatives of LGU leaders are enormous. The astute leaders must keep a firm grasp of the reality in knowing what they need to do to maintain their state of governance and their own political survival (Malayang, B. et.al, 2001). Certainly, there are key factors predispose to the success and sustainability of local NRM. These are pre-conditions that have to be met or constructed—least, progress becomes slow and uncertain. Successful NRM in essence, is fundamentally based on three inseparable elements; technologies, persons and situations (de Leener, 2001), which are, for the purpose of this study, constructed into socio-political- and technical factors.

Within the decade of decentralization, the Philippines has been the focus of many experimentation and intervention in the arena of NRM. It has been a major recipient of various foreign investments that aim to develop technologies, provide support services and design program and policy interventions. Despite this, the number of LGUs responding to their roles in NRM, remains below par. This reality requires a "deconstruction" in our understanding of politics and governments, and our expectations of the Local Government Code as an imprimatur for local NRM. This would mean, determining the complex web of factors that sustains the success of local NRM initiatives—thereby, constructing the conditions that predispose sustainable NRM.

Researchers from the International Centre for Research in Agroforestry (ICRAF) hypothesize that there are policy hurdles, institutional and methodological issues impinging upon the sustainability of local NRM. For example, well-crafted NRM plans can be held hostage by a political exercise, a change in political leadership, or of a shift in national goals and priorities—resulting in a bleak implementation of previously developed NRM plans. Our questions therefore are threefold: 1) what are the conditions predispose to sustainable NRM at the local level?; 2) how can these conditions be constructed?; and 3) how can the national government reconfigure their support to accelerate progress in the NRM sector?

To better understand these, ICRAF, with support from USAID-funded SANREM-CRSP/SEA (Sustainable Agriculture and Natural Resource Management-Collaborative Research Support Program/Southeast Asia) initiated an adaptive research that aims to understand these issues, and derive results that will form the basis for recommendations to the national and local government levels.

BACKGROUND OF THE STUDY

The SANREM research evolved with knowledge products that supported a scientifically-based local NRM planning process in Lantapan, Bukidnon. In 1998, the town Mayor and the Municipal Council committed human and financial resources to the implementation of such a plan, for which there was no precedence in the Philippines (Catacutan et.al. 1999, pers. com.). The municipal government created a multi-sectoral NRM Council, that served as local planning team. The draft plan was circulated and subjected to public hearings, and enacted by the Municipal Council in early 1998. The municipal government has currently allocated 5% of the municipal budget for plan implementation. Ten villages within the municipality have allocated an average of 10% of their budgets for activities outlined in the plan. The initial outcomes of the plan has included a number of new policies and regulations related to natural resource conservation and activities have been implemented for the conservation of land and water resources, and biodiversity (Catacutan, et. al., 1998).

ICRAF's technical contributions to the plan stemmed from its research on agroforestry, conservation farming, and biodiversity conservation. For example, numerous steep ravines emanate from the Kitanglad range out into the agricultural landscape. These valleys are the least disturbed parts of the agricultural area, and they harbor diverse natural communities. They may be valuable in radiating strands of natural biodiversity outward from the protected area into the agricultural parts of the landscape. We worked to develop an appropriate strategy to enhance the biological integrity of the ravines. Glynn (1996) developed a methodology to survey and map the vegetative communities of major ravines of the Alanib River. The maps provided a basis for identifying the hot spots where change in land management practices was needed to protect stream water quality and riparian biodiversity. Based on this information, a ravine habitat management component was incorporated into the municipal Natural Resource Management plan. The communities have now been actively re-vegetating the degraded streambank areas with trees.

The Lantapan experience is a significant advancement in municipality-led and participatory local NRM planning. It is also a milestone in the devolution of planning and management for natural resource protection to the local level, and a major shift from traditional top-down planning approaches towards participatory multi-sectoral planning and research-based decision-making. It emulates the role of LGUs in harnessing local talents and skills in deriving a workable plan using simple participatory methods with minimal investment, as against the conventional hiring of externally-paid Consultants to develop such a plan. In 1998, the DENR recognized the Lantapan experience as a national model for local natural resource management planning in the ***Philippines Strategy for Improved Watershed Resources Management*** (DENR, 1998).

The experience in Lantapan guided our efforts to scale-up to other municipalities surrounding the Mt. Kitanglad Nature Park in the northern part of Bukidnon province (Baungon, Libona, Manolo Fortich, Impasugong). This formed the basis for an Adaptive Research that aims to test the Lantapan NRM planning model to other areas with similar biophysical and socio-economic conditions. Specifically we aimed at:

- testing the adaptability of the Lantapan NRM planning model to other municipalities surrounding the national park;
- determining the key factors that affect the sustainability of local NRM; and
- analyzing their policy implications

METHODOLOGY

The study was initiated through a Technical Assistance Program (TAP) to four self-selected municipalities in Northern Bukidnon. The NRM planning process was completed within a period of 12-18 months, since we were only depending on the pace of the individual municipalities which did not start at the same time. Self-Assessment Workshops were implemented to evaluate the performance and assess the participation levels of those involved in planning. LGU support and leadership issues were also tackled in the workshops.

By then, we developed a survey instrument to determine the respondents' perceptions (98) on the factors that sustain local NRM programs. There were two groups of respondents: elected local government officials, and organic officials from government-line agencies. Majority of the respondents were members of the NRM Councils which served as the planning teams in the municipalities.

With additional resources from the International Fund for Agricultural Development (IFAD), we also conducted country-wide case-studies of eleven (11) practicing LGUs in the arena of Environment and NRM, to verify the study results in Bukidnon, and expand the context-base of this study.

The data were collected and analyzed using both descriptive and empirical statistics. The analyses of results were substantiated with personal interviews of key informants and the results of the self-assessment workshops.

RESULTS AND DISCUSSIONS

Adaptability of participatory NRM processes

From a "local governance" standpoint, **t**he Lantapan NRM planning process is generally adaptable, since it embraces the elements of subsidiarity, equity and multi-stakeholder participation—(the bottom-line of decentralization). The adaptation however, varies with ranges of low, medium and high degree of innovation. For example, all the participating municipalities created their own NRM Secretariat, composed of local staff, who were then, responsible for coordinating planning activities. Some municipalities have longer capacity-building periods, allowing for an internalization process. In one municipality, the Mayor was very much an active participant in the different planning events. Adaptation variability is affected by a sum of factors and local conditions. Foremost are; fund allocation, strength of the local interim NRM Secretariat, degree of interest of the Mayor, and diversity of planning team members. The value added to this experience, was that LGUs were able to overcome the ***institutional constraints*** of initiating NRM planning activities at their level. Further, LGUs were able to ***match the inherent richness of their local experts, with that of an external expert facilitator, exercise full autonomy in planning, and legitimization without having to comply certain bureaucratic orders***, and ***exhaust their financial resources*** for this purpose. The spin-off value is that, the NRM planning activity was conceived in the context of "protected area management" since these are municipalities bordering a protected area. The value-added goal is to compliment the protected area management plan and emulate a "Preventive Systems Approach" to managing natural ecosystems (booklet forthcoming).

What factors affect local NRM?

Conditions predispose to sustainability

Earlier, we identified eleven (11) factors affecting local NRM, and were aggregated into the following: Socio-Political, Technical, and other Intervening Factors. This aggregation appears to be a reconfiguration of the elements of sustainable watershed management and upland development earlier cited in various literatures, re: technical, institutional and policy innovations (ICRAF 2001) and, technologies, persons and situations (de Leener, 2001).

Socio-political factors vs. sustainable NRM

Among the socio-political factors, "***National Mandate***", which is monumentally represented by the 1991 Local Government Code, marked the highest correlational relationship (.80) with respect to sustainable NRM in the study sites. This implies that a national legal framework is significantly important in the pursuit of NRM, upon which local programs can be derived. This signals the need for a decisive top-level strategic planning to set-up a national framework that guides LGUs in the efficient planning and effective NRM implementation. ***Community-based NRM programs*** and models also marked high (.80) correlational relationship. This implies the appreciation and need for a functional participation of local communities. Moreover, this also implies, a bottom-up approach to planning and implementation, given that appropriate participatory tools are made available. A "top-down" & "bottom-up" planning combinations or a "plan-to-plan" approach to planning, appears to be more acceptable. On the other hand, ***national and local protective rules*** posed, moderate correlational relationship (.60). This result supports the relationship earlier established between National Mandate and sustainable NRM. This shows that the social relevance and effectiveness of a State policy can only be judged, if they are strictly enforced, and supported with appropriate local preventive rules, designed to compliment it. While the general perception of people about rules is about tyranny, this finding proved otherwise. This is also supported by the political theory of Thomas Hobbes (1657) which states that, "*the State can not be in a state of nature, where men are loose; where man is enemy to every man; where men live without security; where there is a great deal of grief because there is no power able to awe them all*". Protective rules are not suppose to suppress rights nor penalize the violators, rather, it is suppose to provide incentives to those who obey the rules. Policy incentives can form part of a social contract between the governed and the governor. However, such political reforms may require much greater commitment and a virtual overhaul of the political space. Local ***Political Culture*** also posted moderate correlational relationship (.60) to sustainable NRM. Accordingly, this is related to the above-result. The political culture defines the condition that is conducive for a collective action to take place. It transpires from a social capital formed by the "governors" and the "governed" to work together for a common good. While the political culture is formed by an interplay of characters, norms, rules and situations, in the context of local governance, it largely refers to the political will and leadership of local leaders.

Technical Factors vs. sustainable NRM

Among the technical factors, support from ***External Technical Agencies*** (eg. Research Institutions, NGOs, banks, etc.) and ***Local Technical Capabilities*** exhibited high correlational relationship (.80). Clearly, external expertise are recognized to match the richness of local experts. However, building a functional relationship and participatory arrangements between local technical people, local communities and the external support providers require a great deal of facilitation. On the other hand, availability ***of participatory tools and approaches*** posted moderate correlation (.60). These tools are important in improving public participation.

Other Intervening Factors

Earlier, we identified two intervening factors for sustainable NRM. They are: *Local Financial Investment and Local Environmental Conditions.* Interestingly, ***Local Financial Investment*** obtain the highest coefficient of determination (.85) among all the factors presented. This means that the sustainability of NRM implementation rest largely upon the LGU's internal financial investments. Among other prominent socio-political and technical factors, LGUs perceived that their own expenditure assignment can sustain the success of local NRM. Following this are: L***ocal Technical Capabilities*** (.71), ***Political Culture*** (.69), and ***National Mandate*** (.60), respectively.

The above-results were verified through case-studies of twelve (12) nationally recognized successful LGUs in NRM. A synthesis of the case studies revealed substantial similarity, with those of the main study sites (north Bukidnon).

The key findings are:

- Successful LGUs are those who have allocated their own local funds from either the general or local development funds, as part of their annual investment plan.
- These LGUs have created their local "Environmental and Natural Resource Management Office" (ENRO), as a regular division of the LGU, with staffing support and annual budget allocation. Some LGUs created an interim, but functional ENRO from the ranks of local staff. This necessitates special manpower re-alignment and innovations within the institution. We learned that the impetus for the creation of local ENRO, was not necessarily the "loose mandate" of the Local Government Code. Some of LGUs, were inspired by their own vision to make a difference and break-away from conventional politics and governance.
- Local policies were promulgated to support the local implementation of environmental programs.
- The main driver of NRM emanates from strong "political will and leadership" of the local leaders, usually, the municipal/city Mayors and provincial Governors. NRM programs transcend beyond the political terms of a chain of proactive, modernist

  and radical leaders. The caveat however, is that, political will and effective leadership is an elusive commodity, and is hardly replicable.

The sequential order of the sustaining factors follows a very practical logic. Also, it carries a brighter promise, if these perceptions can be attributed as impacts of the Local Government Code. The LGUs recognize that their own financial and human resource investment within a sound political culture will sustain success in local NRM, supported with a clear national mandate. The conditions predispose to the sustainability of local NRM are firmed from these factors, and herein iterated:

- LGUs must ensure a continuous flow of funds available for NRM investment from three potential sources of funds: the general fund, the local development funds (LDF), and from self-generated funds from various public or private sources. These should be incorporated in the Annual Investment Plan.
- LGUs must install an institutional infrastructure by creating a functional ENRO, with technically qualified staff, capable of overcoming constraints to their ability to shape and enforce policies and programmes.
- LGUs must endeavor to create a political culture, away from "partronage politics". A political culture that is proactive, catalytic, and inclusive of paradigm shifts in development and government systems.
- LGUs must be clarified with some of the "conflict-generating" national policies, particularly, their devolved functions, powers, and jurisdiction.

Given the above, we need to examine certain provisions in the Code, hindering such conditions at the local level. Section 3 of the Code (Operative Principles of Decentralization: LGC 1991) provides that "*LGUs shall share with the National Government the responsibility in the management and maintenance of ecological balance within their territorial jurisdiction, subject to the provisions of the Code and national policy"*. This general provision however, sounds categorical with respect to Environment and NRM devolved functions to the LGUs. A closer reading of the Code indicates that local autonomy in NRM is at best, limited, and at worst, ambiguous (Manasan, R., 2001). The Code transfers responsibilities of community-based forest and watershed projects, but not the appropriate authority. The national agency (DENR) retains its supervision and control over those projects. Moreover, the Code provides an optional mandate in the creation of local Environment and NRM Offices (ENRO) at the municipal, city and provincial levels, and therefore, fund allocation for ENR management activities is held under the prerogative or mercy of the Local Chief Executive. Such typical weakness in the devolution process results in a complacent attitude among public officials. The Code (Section 17) also encourages the continued involvement of central agencies on functions assigned to LGUs, by allowing central agencies to implement and retain control over projects funded by the General Appropriations Act and Foreign Agencies. Under this situation, national agencies tend to direct LGUs behavior towards national goals, (while acting local), since they are made accountable for the outcomes of those projects. This is aggravated by the prevailing regulatory framework, permitting the "two-track delivery system" where both central agencies and LGUs can initiate devolved activities (Gonzalez, 1996; Manasan, 2001). As a result, LGUs are confused with what exactly are their responsibilities, consequently, public accountability becomes unclear of LGUs and the central agencies.

How do we enhance or construct these conditions?

Policy implications at the national level

To construct the conditions cited above requires a two-pronged approach.

Firstly, the National Government need to reconfigure its support to meet these conditions. A first wave of action would be to launch a sectoral re-examination of the gains and pitfalls of the Local Government as it embarks another decade of implementation. Specifically, the following actions may have to be prioritized:

- The national government should make necessary amendments with respect to certain provisions that are unclear in the Code, particularly, the delineation of expenditure assignments of Environment and NRM functions.

- The national government should stop showing symbolic gestures of interest by enclosing certain percentage of NRM funds in the "Budget Circular" for LGUs, just like how budget circulars for Gender and Development, Anti-insurgency, and Drug Prevention budgets are imposed. Otherwise, budget circulars for Local Development Funds should be lifted, thereby, allowing LGUs to exercise full fiscal autonomy, such that, NRM programs can be easily funded without restrictions.

- The national government should make amends to the "loose mandate" in the Code, stipulating the optional creation of ENROs at the municipal, city and provincial levels. The creation of local ENRO should be mandatory to effect a full devolution of environment and NRM functions.

Secondly, the National Government need to revisit the programmatic areas of good governance by:

- Reviewing and making necessary amendments with more than a thousand environmental laws, that are most often, conflicting, if not lacking, with appropriate enforcement.

- Institutionalizing an effective training program for LGUs to capacitate public officials and devolved technical personnel. The fulfillment of a multifaceted role of LGUs would depend upon the administrative, managerial and technical capability of local administrators and officials. Their capacity can be raised through the undertaking of an appropriate, relevant and training program (Oamar, P., 1998). This broad stroke will hasten the construction of a political culture inclusive to NRM concerns. The Department of Interior and Local Government may need to take a lead role in developing this capacity-building program, with some help from allied agencies.

- Clarifying the devolved roles, functions and powers at the local level.

- Taking a bold role in elevating NRM as a basic social service, along with health, nutrition, social welfare and education.

- Benchmarking and identifying indicators for successful NRM should be clarified, and minimum standards required for each locality.

- Applying the systems approach as a Framework for understanding local government dynamics and systems.

IMPACTS OF THE STUDY

The study had socio-political relevance in the quest for an improved and sustainable NRM. It has contributed in the debate about good governance, sustainable development, NRM policy reforms and the shifting of frontier development initiatives. As a public good, the results are now used to analyze appropriate policy reforms needed in promoting local NRM. Policy makers and development practitioners can take advantage of the experiences and lessons of the municipal study sites, as an indicative template in formulating their own NRM plans and providing support policies. The study maybe also helpful for researchers, towards evolving a conceptual framework that effectively captures the imperatives of an Integrated NRM (INRM) Research Framework. Involving LGUs in the agenda of a Sustainable Agriculture and NRM Research remains a new business, despite the intention to include this within the last decade. We cannot avoid recognizing that the concepts available for scientific discussion concerning this desired shift are rather poor (de Leener, 2001). But the pressures of advancing the social relevance of technical research are astounding, that the research community needs to change gear in the way research agendas are formulated and implemented. The pluralistic nature of research goals, at least, beginning the last decade necessitates a multi-tiered and interdisciplinary approach. The outputs clearly, contributed to a clarified understanding of the socio-political environment, predispose to the successful generation of scientific knowledge, and the delivery of knowledge products to user groups, at a scale transcending beyond institutional, temporal and spatial constraints.

TRANSFERABILITY OF EXPERIENCE AND FINDINGS

Decentralizing countries in the region would benefit from the lessons and insights gained from this study, and SANREM can provide the venue for knowledge-sharing among these countries, reinforced with future ground research work in areas it could possibly expand. Although, context-specific conditions have to be considered, the general conditions hold true in most developing countries, and therefore, the transferability of study framework and results-sharing can be realistically achieved. Within SANREM, this calls for a serious commitment to one of its "cornerstone", the "Interdisciplinary Approach", requiring stronger cooperation among social and biophysical scientists, as well as, policy analysts.

CONCLUSIONS

Although, decentralizing governments are grappling in understanding the concept and good practice of "decentralization", it does, by far have milestone gains (Catacutan, D. ,2001). The decade of Philippine decentralization is a honing phase towards the fulfillment of a "fuller" democratic government. The LGU perspectives of sustainable NRM is a manifestation of a maturing understanding of good governance, under the decentralization theorems. The challenge however, is to keep abreast of local realities needing a constant re-examination of national policies supportive of local initiatives. In this case, there is a pressing need to deal with first generation issues to accelerate progress in the NRM sector. Foremost, is a policy reform that include the establishment of an institutional infrastructure and providing financial support thereof. NRM expenditure also derives socio-economic benefits, therefore, it should be elated as a basic social service. An important lesson for "would-be" decentralizing countries is to make adequate preparations at the local level including, re-orientation and training of public officials and local staff, re-engineering institutional structures, ensuring a critical mass of support, developing appropriate technical capacities, and providing financial mechanisms.

A better understanding of technological changes requires better understanding of socio-political changes. If fact, technology adoption is much of a social fact. We can not talk about technologies alone, *but we should talk about a particular technology of these particular people under that particular situation* (De Leener, 2001). This has implications in which agricultural research agendas are developed and implemented. This may require a multi-faceted paradigm shift for the research sector, so that, technologies generated from good science can truly deliver goods of public social relevance.

Such trends on Global Partnerships Programmes (GPP) and CGIAR's (Consultative Group on International Agricultural Research) Challenge Programs require a multi-tiered stakeholder involvement in designing and implementing research programmes. Along this line, the frontier institution at the local level, remains to be the Local Government Units, whose direct management influence and control over their territorial communities reflect the quality of community life. It is therefore, important to continue working with them, in understanding their conditions, and filling-in some information gaps that help them become better decision-makers and resource managers.

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Relationships Between the Global Decision Support System and Regional Projects
SANREM II - A Conceptual Framework [1]

Neville P. Clarke[2]

ABSTRACT

SANREM research involves development and application of methods to enhance the sustainable use of natural resources to achieve the USAID goals of improving food availability and economic growth. The current mandate is to provide improved tools for decision making at landscape/lifescape, sub-national, national, multinational, and global levels. How can we make the best use of the total SANREM resource to address the broader mandate? What is the appropriate level of engagement and integration between global and regional projects? Regional projects are extending community-based methods to other communities in different locations and developing applications for decision makers at higher levels of scale. The Decision Support System involves development and application of economic, environmental, and biophysical models in East and West Africa to support decision makers at multiple levels of scale. Collaboration with FAO is developing a global system of models and databases for use by national programs. In this paper, we suggest both parallel and linked approaches between projects including a combination of communication, coordination, and collaboration – three different levels of engagement. The paper provides a basis for discussion at the Synthesis Conference to review present status and plan future relationships to help ensure the pieces of SANREM fit together.

INTRODUCTION

Scientists and managers in the SANREM CRSP projects are presently involved in research in the fourth of a five-year cooperative agreement with USAID. This is the second such agreement with the Global Bureau. The annual SANREM meeting provides an opportunity to assess progress and consider plans for the final year of SANREM II. There is need to consider how to put the results together and to shape the final year of research to make the SANREM II product as responsive as possible to the sponsor's mandates. There is also need to consider the strategy for SANREM III. The Management Entity has provided their plans for the development of this strategy (9/20/02), forming a point of departure for discussion at the coming meeting. The timetable for developing the overall strategy for SANREM III is very tight. The key interactions among players need to occur, as much as possible, at this meeting. The results of these deliberations must be reflected in year-five plans for SANREM II and in proposals for SANREM III.

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HISTORICAL CONTEXT

The University of Georgia recruited new leadership for SANREM II. However, there was considerable valuable continuity in participants being involved in the regional projects under both SANREM I and II. Texas A&M became part of SANREM as it began its second five year agreement with USAID. The historical perspectives about this are different among key players. Some of the points in this history are contentious and, do not seem to contribute to a productive debate about the future. However, there are a few key historical points that are important to our planning at this point. These are presented with the notion that they may be debated and, as necessary, modified during the meeting.

USAID has, as one principal focus, the development of ways to enhance food security and develop economic activity while making sustainable use of natural resources. As a global agency, they are seeking to develop public goods (processes and products) that can be used at levels of scale ranging from local to global. In moving from the first to the second SANREM agreement, the sponsor continued to value the SANREM approach in sustainable development and natural resource management at relatively local levels. But, they also sent a clear signal of their interest in creating products that meet their objectives at levels of scale above the household, village, watershed, and landscape.

At the time SANEM II was being defined, Texas A&M had ongoing research for USAID on development of holistic methods to evaluate economic, biophysical, and environmental consequences of policy and technology options to sustainably enhance food security in developing countries. The continuation of this research was incorporated into and funded under SANREM II as part of the global subproject. In year four the TAMU component became a separate.

One of the overall goals of SANREM is to create program integrity that ensures the parts of the project are complimentary and that the overall goals of the sponsor are met. This paper is about the issues and opportunities involved in achieving that goal.

MOVING AHEAD IN SANREM II

During SANREM II, the three regional projects have in part evolved to take methods and principles developed in SANREM I to application at other locations and levels. This has involved both lateral and vertical transfer. Lateral transfer is defined here as taking technology from one location to another at the same level of scale, ranging from household to watershed. Vertical transfer is defined here as the application of results or methods developed at smaller levels of scale such as village or watershed to provincial, national, or multinational levels. The regional projects have not evolved at the same pace. For instance, the Southeast Asia Project is well along toward its vertical and lateral evolution, while the West Africa Project, as a new start in SANREM II, still concentrates its effort at a relatively local level. The products of the regional projects include methods for participatory planning and actions aimed at sustainable use of natural resources for food security and research to develop new practices and technology to meet these same objectives.

The project to develop and apply the Decision Support System (DSS) has involved development of methods and their application to a set of priority issues identified by decision makers at varying levels of government. A participatory process is also being used here with the participants being decision makers at varying levels involved in defining their needs, participating in development of methods and products, and evaluating outcomes. The participatory process here, as it is in general, is critical to the successful building of capacity and ensuring use of products. The DSS project is conducting research in Mali and adjacent West African states, in Kenya and adjacent East African states, and at the global level in collaboration with FAO.

The DSS is a suite of economic, environmental, and biophysical models that is being developed at levels of scale from household to multinational. A major element of the research is to develop the means of linking these models in a geospatial framework to provide a holistic approach to assessing the options facing decision makers on the use of natural resources to sustainably increase economic activity and food security. In this respect, the models and related databases are central to the overall objective of SANREM to provide results that range from local to global in their application. As the system evolves, there is recognition that the name of the project does not fully convey its science and application. A more meaningful description might be something like "Precision Landscape Analysis System". This is still under consideration and mentioned here only to reflect the evolution of the current effort and the implications on future directions.

LINKAGES OF REGIONAL PROJECTS AND DSS

Over the course of SANREM II, there has been ongoing discussion of more explicit linkages between the DSS and regional projects. The External Evaluation Panel and the Management Entity have encouraged the development of these linkages. Because of the co-location of research in West Africa, plans were made for the first such linkage between DSS and the WAP. There are specific year-four plans for this engagement. The collaboration has been paced by the need for the WAP to achieve consensus among its participants on the next steps in their program.

Why have we not developed a more interactive engagement between the regional projects and the DSS? Looking back is useful if it helps to identify problems to be solved as we move ahead. The DSS has two operating locations and an ambitious research plan. Two of the regional projects are in different parts of the world. Developing models and databases for new locations is resource intensive. The EEP has noted that the project is spread thin with its existing resources and has encouraged it to ensure that it has sufficient focus to ensure a viable product. The WAP has not matured to the point where there is an internal mutual consensus among collaborators of how to implement the collaboration. While there are some substantial common threads, there are substantial disciplinary and cultural differences between the regional projects and the DSS. Our challenge is to take advantage of this diversity to achieve the common goals of SANREM II – which is to provide tools and results that help decision makers at multiple institutional and governmental levels. As the methods and models in the DSS are evolving, substantial progress is being made in generating more utility of the system. In the future, it will require less resources to apply the DSS to new scenarios than in the past.

For collaboration to be effectively done in the future, in SANREM III, the engagements will need to be part of the initial plans of the various SANREM players. The experimental design of the related projects must include the explicit details of the collaboration from the start. ***A clear perception of mutual benefit must be achieved and a commitment to the collaboration made.***

ACHIEVING SANREM PROGRAM INTEGRITY

The USAID mandate for SANREM II is to provide products that can be used at levels of scale from local to global. The mix of global and regional projects lends itself well to achieving this goal. But, program integrity does not mean that all parts of SANREM II have to be intimately integrated. Program integrity can be achieved by varying levels of linkages that include effective communication, cooperation, and collaboration. With important recognized exceptions, it seems fair to say that the regional projects have focused their efforts on relatively local levels of scale. The DSS has focused on engagements with decision makers at higher levels of scale – provincial, national, multinational, and global. Figure 1 is shows a concept of how the two approaches might have a useful intersection.

While opportunities for collaboration might be recognized at any level of scale, it would seem particularly fruitful to look for these possibilities at the intersection of the global and regional parts of the overall project. It is here that some of the methods and results of local participatory driven activities might find application in upward scaling and where the outputs of national models (markets and prices) might be valuable inputs to more local models and strategies.

Figure 1
Relative areas of emphasis and potential intersection of Global and Regional Projects

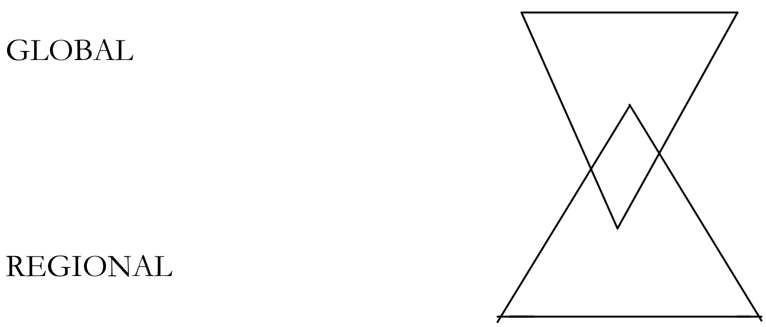
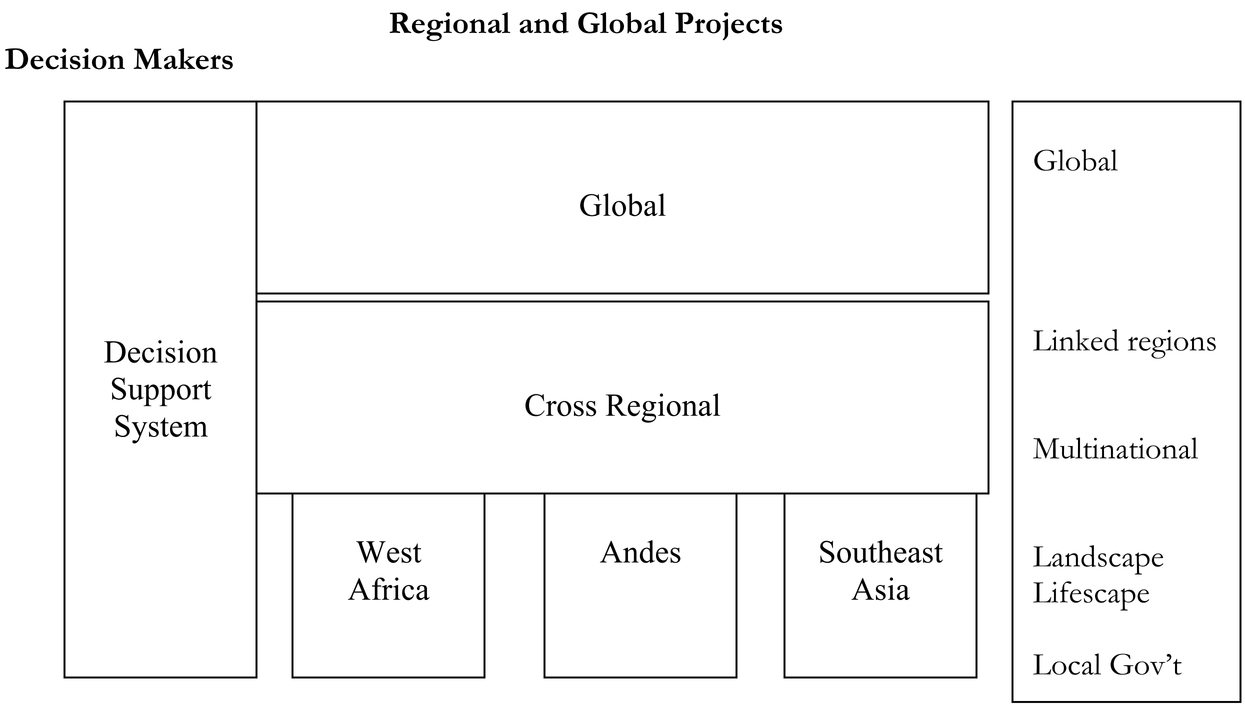


Figure 2 depicts a concept of the relationship between the DSS and regional projects. It shows that the two kinds of activity may usefully evolve either in parallel or in tandem. The three regional projects are, to varying degrees, applying products developed at local levels to other locations in the region – both within countries and between countries. The regional projects are also defining and documenting cross regional implications of their individual results. A cross regional comparison between the DSS East and West Africa studies is part of the year-four plan of work. Cross regional products logically progress towards global interpretations of results. The DSS involves modeling from farm or household to global levels. However, it does not develop the detailed methods and results at household and village levels that are done in regional projects. The DSS is involved in developing methods that explicitly link and upwardly aggregate the results of the holistic analysis done using the integrated suite of models.

Figure 2
Relationships Between Global and Regional Projects
Relative to Decision Makers and Level of Scale



The ability to aggregate economic and environmental models and their results to larger levels of scale remains a challenging research area, although workable solutions are becoming available, if imperfect. This is an area of continuing research for the DSS and presumably with the regional projects. This is a capability that the regional projects will ultimately need to take their local results to larger levels of scale.

An example of complimentarity is the varying levels of complexity of models and related expertise required to use them. The regional projects, at least in part, focus on providing farmers and village level decision makers with tools they can use themselves. The DSS is inherently more complex and one of its challenges is the packaging of the models into a common framework that provides access and utility to users with varying levels of modeling skill. Clearly both kinds of capacity are needed to meet the broad USAID mandate. But the same model does not need to be used at all levels. It could and should be possible to provide interfaces between models, in cases where it is useful to do so.

How does this stack up with regard to the overall USAID mandate and the commitment to SANREM program integrity? In the short run, SANREM can provide useful tools to decision makers at all levels including households and villages and higher levels of government using complimentary methods. These methods and databases are not necessarily closely integrated and analyses can be done independently between the DSS and regional projects. In other words, SANREM is covering its bases in terms of both institutional and biophysical scaling by the complimentary set of tools being developed. On the other hand, not all the DSS models will find utility in the more site-specific local applications and these local applications developed by regional projects will not always be useful in analyses at broader levels of scale. Program integrity could and probably should be considered more at the conceptual level – where general principles of modeling and analysis are complimentary.

BACKGROUND FOR PLANNING SANREM III

Year-four activities are well along in the regional projects and DSS. The objective of linking the DSS in Mali with the West Africa Project remains to be achieved and the planning sessions at the annual meeting offer good opportunity to re-examine the details of the engagement and develop a timetable for getting underway. For the DSS, year five will require substantial effort in documenting models and data bases as well as continuing to develop methods for developing country partners to access and use these products. Year five is also a time when detailed planning of SANREM III can be accomplished. The areas of engagement to further build program integrity in SANREM III need to be defined as proposals are developed in early 2002. There are several general issues for which additional clarification and guidance would enhance our planning capability.

- Planning SANREM III obviously provides opportunity to revise the overall strategy and to create substantial new change from a programmatic and process standpoint. Creating needed change in the course of continuity of long-term objectives should be the mission.

- It will be important to know of any strong guidance coming from the sponsor at the time of planning of the new agenda, rather than later. Are the general premises of SANREM I and II still valid? Is the sponsor still expecting the program to cover the range of scale from household to global? What, if any, changes in philosophy and general direction does the sponsor envision?

- This meeting provides an opportunity to place new issues and opportunities into the context of the ongoing program to develop an enlightened overall agenda for SANREM III. It is important that the Technical Committee looks past the current effort and ensure a forward facing agenda that addresses the issues of sustainable development that will be most relevant over a 5-15 year time frame.

- It is important to consider restating the SANREM strategy to more explicitly link the sustainable use of natural resources to the explicit goals of USAID to reduce poverty and enhance food security. This seems understated in the draft strategy of the ME.

- Institutional strengthening is unfortunately severely limited by the constrained institutional funding in almost all developing countries. The need is for actions outside the immediate purview of the CRSPs to provide an institutional framework on which we can build specific programs. How to achieve this is not an easy question to answer. Institutional strengthening would be better considered in the context of the government as a whole, not just the research and teaching institutions with which we collaborate.

- We would like to be doing more short term as well as long term training to provide a capacity to use the methods we are developing. We, as other parts of SANREM, believe that the most effective method is through active participation in planning, conducting, and evaluating the results of research. Collaborators can then become teachers and practitioners when our job is done.

- Research is the engine that drives outreach and extension, education and training or institutional strengthening. It is suggested that, in the overall SANREM III planning, it would be appropriate to examine the balance between research and outreach. Without a relevant base of new knowledge upon which to build, the other parts of the SANREM mission could perhaps be as well or better done by NGOs, PVOs and others

NEXT STEPS – CONTINUING AND EXPANDED AREAS

In looking forward to the next round of SANREM, The Texas A&M Impact Assessment Group has identified a number of issues and opportunities that could be a part of the new program. Some of these represent continuation of current work; many are what seem to be logical additions or new directions to build on the fundamental precepts of SANREM. A number of these areas appear to lend themselves well to consideration for either coordination or collaboration with the regional projects. They are suggested as topics for discussion at the Annual Meeting.

Linked Models: We believe (with admitted bias) the ability to link environmental, biophysical, and economic models that can be applied at varying levels of scale is fundamental to the overall goals of SANREM and that additional emphasis should be placed on this area of research. Biophysical and environmental upward scaling moves from field to farm to watershed, while economic scaling moves upward along politically defined boundaries, since this is how secondary economic data are acquired and stored. Methods to improve the ability to link upward aggregation of biophysical, environmental, and economic data are badly needed.

Putting Models to Practice: In SANREM III, there is the opportunity to put the methods developed in SANREM II to practice at several levels of scale. For example, the use of satellite imagery combined with biophysical models of crop-livestock farming systems could be developed to provide forecasts of agricultural outcomes within and between cropping cycles. Such estimates would be central to improving the current FEW system, especially in West Africa.

Global Climate Change: The impact of global climate change on small farmers in the South, taken at a macro level, is predicted to be very substantial. More specific knowledge is needed on how global climate change will affect these operators, and on strategies to reduce the impact of climate change, including alternative production practices that are sustainable over time. Answers involve environmental, economic, and biophysical aspects linked in a holistic approach to analysis.

Measuring Status of Degraded Lands: Methods are needed to measure progress toward achieving restoration of degraded lands or to measure the impact over time of production practices with varying levels of threat to sustainability of natural resources. Estimates of soil carbon may provide one such indicator. The use of modern satellite imagery coupled we new point-based infrared reflectance monitoring technology could provide an affordable approach if the methods are sufficiently accurate. Similar methods are needed to improve the ability to assess the status of water quality and quantity as a function of agricultural and forestry practices.

Understanding Markets: Farmers and regional, national, and international planners concerned with improving food security and economic growth all state that they believe one of the key factors is providing better methods for smallholders to understand and operate in increasingly complex local, regional, national, and international markets. It would be very important to include this as part of the total systems approach taken in SANREM III.

Livelihoods: There should be useful opportunities to define relationships between the methods used in the DSS and those less quantitative approaches used in livelihoods analysis. Some elements of the product could be useful in assessing the impact of SANREM and its component parts.

Unifying Principles for Scaling: One of the more important but difficult issues is how to provide the development of methods used to relate research done at one level of scale to others and to build unifying principles that allow for scaling research results or experiences up or down as we develop and improve methods for use by decision makers.

Indicators of Ecosystem Health: For NRM in general, there needs a better set of metrics or indicators that allow one to quantitatively assess the impact on ecosystems of alternative policies or technologies that are intended to enhance food security and reduce poverty. This metric is probably not entirely an economic one. It is more complex than just estimates of water and soil quality.

Better Linkages Between NRM and Food Security – Poverty Reduction: More emphasis is needed on development of methods that explicitly and quantitatively link the environmental and natural resource consequences of methods to enhance food security and reduce poverty through intensification or extensification of production practices under varying developing world conditions.

Capacity Building: Texas A&M is actively seeking funding outside SANREM for substantial regional capacity building efforts in both West and East Africa. Working with regional associations and national programs, we are proposing to establish research and demonstration units in key countries where teams of people from national programs in the region can learn to use the DSS. This will be collaboration between regional associations and SANREM.

Global Decision Support System: Texas A&M and FAO are collaborating to raise funds move from the East and West African experiences with the DSS to the establishment of an FAO-based global network of models and databases that can be accessed and used by developing and developed country analysts. We plan to include ICASA as a part of this collaboration.

CONCLUSIONS

Our assessment leads us to conclude that the separate regional projects and the DSS justifiably have relatively distinct agendas that address the SANREM program in complimentary ways. We believe there is good program integrity in the overall project. We do not believe that all parts of SANREM must be closely integrated to achieve overall program integrity. However, we conclude that there are opportunities to improve program integrity by better communication, coordination, and, in some cases collaboration between SANREM elements. In SANREM II, we learned that this requires a perception of mutual benefit among players and a strong commitment to action.

When the draft approach on strategy provided by the Management Entity and the agenda for the research conference were considered, it was the feeling of our group that we needed to bring better balance to the overall discussions about current and future directions of SANREM. We feel more consideration should be given to the goals of SANREM at larger levels of scale and with decision makers at levels above the local scale. We felt that this would provide opportunity to show how the overall project is meeting the goals of the sponsor and provide the venue for some serious planning about how to better work together.

Our group met November 5, 2001 to review and extend our discussions on future directions for our overall activities, including SANREM. This provided input from the Group to use in this paper. However, I should say that time constraints precluded a chance to provide for adequate review by my colleagues. Accordingly, I hope that you will not blame them for either sins of omission or commission in these remarks. Carlos Perez was kind enough to provide some extra time to complete preparation of this paper after our Group met last week.

Colleagues participating in the SANREM Research Conference are asked to forgive this obviously one-sided treatment of the interface between the Decision Support System planning and thinking and that of the Regional Projects. This was done with the intent of bringing a better total balance to the conference and, most certainly, to the deliberations about future relationships between regional and global projects. We did not wish to presume to address theses issues from the viewpoint of the regional projects, but rather to present our ideas of where useful interfaces might exist. It is our hope of that this will stimulate colleagues in other parts of SANREM to surface their own topics for discussion of our interface and to elicit guidance from the sponsor and management entity.

We sincerely hope that the agenda for the meeting will provide time when the issue of interface between the DSS and regional projects can be given appropriate consideration. We reckon that unless this occurs then, there it will be difficult to have face-to-face discussions before it is time to prepare reports and proposals.

Economic and Environmental Impact of Improved Sorghum and Millet Technology in Mali[1]

Bobby R. Eddleman[2], Alpha O. Kergna[3], Jeffrey Vitale[4], Bruce A. McCarl[5], C. Chen[6], and Paul Dyke[7]

ABSTRACT

To provide improved methods to assess the impact of introduction and use of technology, a suite of integrated interactive models was created for use in developing countries. The Agricultural Sector Model (ASM) was used to estimate the economic consequences of adopting a new sorghum production system derived from joint U.S. and Malian research under the INTSORMIL CRSP and ICRISAT. It assumed an adoption rate of between 20 and 30% among regions of Mali. Demand is based on estimates of population growth in the year 2015 (World Food Summit target date) for the various regions of Mali. The annual total national welfare associated with adoption of the technology was estimated to be FCFA 635 billion per year in the year 2015. The EPIC model was run with 20-year simulations. The model predicts a reduction in erosion using the new production system ranging 1-3% in the Segou region; 30-43% in Kayes. The reduction is attributed to faster development of canopy cover exhibited with the new system. This is due both to the improved germplasm and the increased use of fertilizer. These results suggest the economic benefits of the new production package are accompanied by positive environmental consequences through reduction in soil erosion.

INTRODUCTION

One of the challenges confronting policy makers in developing countries is satisfying their country's food demand goals set by the World Food Summit for the year 2015. In the West African Sahel (WAS), high population growth is expected to pose a major concern. With fast growing populations and recent stagnation in production, the 2015 food targets in the WAS will remain somewhat Spartan in nature. Here, the food target goals will focus on assuring subsistence levels of basic food items to its citizens. To keep pace with the growth in population, food production will need to grow at about an annual rate of 3 percent throughout much of the WAS.

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In the past, it would have been much easier for to meet the increased food demand through area expansion using traditional technology. But today, with the supply of quality lands exhausted throughout much of the Sahel, area expansion amounts to marginal land clearing. Yields decline as farmers push onto the marginal lands, and over time the removal of land cover results in accelerated land degradation. If prudent land management practices are not followed, the process of continued land expansion poses a serious threat to the environment, as well as to societies food security (Scherr and Yadav 2001).

The rising land costs in the Sahelian areas has prompted interest in the semi-humid frontier areas of the WAS. These regions are free of the soil moisture constraints that limit production in the Sahel, and generally the supply of quality land is not as much of an issue in the semi-humid tropics as it is in the Sahel. The push onto the sub-humid frontier has been made possible through investments in public health and infrastructure, which have allowed farming communities to increase dramatically over the past two decades (McMillan et al. 1998). Being more responsive to intensification, these higher productive areas have experienced a significant amount of new technology introduction. The primary crops that typically have been intensified have been cotton and maize, cash crops that have attracted support from private and semi-private sources (e.g. CMDT). However, staple food crop production has received substantial co-benefits in this region. Sorghum and millet productivity is enhanced from the higher levels of input usage that is generally available from the more developed input supply channels, and in the low lying "bas-fonds" areas, there are substantial opportunities for production in rice, Irish potatoes, and vegetable gardening.

Even with an emphasis on the higher productive frontier, the drier Sahelian areas should not be ignored (Vitale 2001). Although area expansion is no longer a viable option in the Sahel, new technology offers an alternative to increase production through raising yields on lands already cultivated. Research stations throughout the West African Sahel have demonstrated the ability of new technology to raise land productivity to heights far above traditional technology (Matlon 1990). Moreover, new technology is likely to mitigate resource degradation since farmers would allocate more of their resources to the higher quality fields, and would turn their attention from the marginal lands.

Another consideration for policy makers is to determine which commodity, or portfolio of commodities, to focus technology introduction on. In the WAS, there are four cereals that can be used to meet basic food requirements: sorghum, millet, rice, and maize. Rice and maize perform well in the semi-humid areas and have a greater response to intensification under improved growing conditions than do sorghum and millet. Recent shifts in consumption patterns have tilted towards rice and maize as opposed to sorghum and millet (Reardon 1993). Alternatively, the traditional cereals (sorghum and millet) require much less demanding growing conditions, and outperform rice and maize in the harsher Sahelian agro-ecological zones. As a result, sorghum and millet are produced over a much larger area than are rice and maize, hence allowing for smaller productivity gains to achieve the same aggregate effect as rice and maize. Moreover, sorghum and millet have a long and established consumption pattern that is not expected to experience further declines over time, particularly so in the rural areas.

This paper considers the role that new technology would play in achieving the World Food Summit 2015 target demands for the staple crops. Technology introduction in both the drier Sahelian areas, as well as the in the semi-humid frontier, are considered. To do this, a sector model was constructed to estimate the societal impacts from new cereal technology introduction, and to determine the extent to which they can empower societies ability to reach the World Food Summit 2015 targets. The sector model approach allows for a comparison between the impacts from both the Sahelian and semi-humid production zones, as well as the potential for cross commodity comparisons.

This paper begins with a brief description of Mali, the country that was chosen for a case study. Next, the sector model is presented in a descriptive format where its basic functions are explained. A data section follows this, where model parameters such as yields, future food demands, and adoption rates are detailed. Then a description of the four new technology introduction scenarios is presented, followed by the sector model's results. The paper concludes with suggested policies, as well as implications for future research.

BACKGROUND

Mali was chosen as a case study since conditions in Mali are for the most part typical of other countries in the WAS. In Mali's Sahelian region, the major challenges to agriculture include high population growth rates that average about 2.5 percent throughout the region, recent stagnation in food production from poor food policies and dwindling land supply, as well as increasing concerns over its natural resource base and accelerating resource degradation. However, Mali also has opened substantial areas in its semi-humid frontier areas located in the Sikasso region, which has become one of the more successful stories in agricultural development in West Africa (Sanders et al. 1996). Here, cotton yields have increased nearly four-fold since the early 1960's, and maize yields have experienced productivity gains nearly as large.

Mali has three main agro-ecological zones: Sahelo-Sudanian, Sudanian, and Sudano-Guinean[1] (Figure 1). In terms of production area, over 45 percent of Mali's land area is in the driest zone, the Sahelo-Sudanian, while the high potential Sudano-Guinean zone contains only 22 percent of the production area. The remaining 33 percent is in the Sudanian zone (Vitale 2001). Most of the staple food production takes place in the drier Sahelo-Sudanian zone and Sudanian zone. Total cereal production in these two zones (excluding rice) is over twice as large as cereal production in the Sudano-Guinean zone (RSSP 1998; FEWS 1997; Vitale 2001). However, maize production is primarily limited to the wetter Sudano-Guinean zone, where over seventy percent of Mali's maize is produced.

Although staple food production is dominant in the drier two zones, the high potential Sudano-Guinean zone produces the largest value given its propensity for cash cropping. The total value of crops produced in 1996 was estimated to be about $ 205 million in the Sudano-Guinean zone (Vitale 2001). This is about one-third more than the value produced in the Sahelian zone, even though total production area in the Sahelian zone is over twice as large as the Sudano-Guinean zone. The Sudanian zone produced about $ 169 million in crops in 1996, about 15 percent less than the Sudano-Guinean even though the Sudanian zone has a 10 percent larger production area.

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[1] Average annual rainfall in the zones are as follows: Sudanian zone (350-600 mm), Sudanian zone (600-800 mm), and Sudano-Guinean (800-1,100 mm).

METHODOLOGIES

An agricultural sector model (ASM) for Mali was constructed and used to estimate impacts from new sorghum and millet technology (McCarl et al., 1980). A primary feature of ASM is its ability to estimate how prices would change if new technology were introduced. It does this by simulating market outcomes in each of the major cities. The aggregate supply from the surrounding farm population enters each market, and consumers make their purchases depending upon the prevailing price. The ASM determines the price in each market in a manner that is believed to be consistent with how free, competitive markets function. In equilibrium, market prices are such that throughout the country, all producers have maximized their profits, and consumer's preferences are best satisfied given their income.

Two types of consumers are included in the model. Subsistence level farmers are presumed to retain sufficient food for family consumption to meet specified minimum caloric needs, along with tastes and preferences before products are marketed. Market-based consumers in the cities maximize their utility of preferences, subject to budget constraints. Producers maximize their profit given a production technology and prices; therefore, the supply function depends on prices and technology.

Aggregation of each consumer demand function and each producer supply function results in market demand and supply functions. As explained, in competitive markets, social welfare is maximized when all markets are in equilibrium. That is, maximum welfare will occur at the intersection of the market demand and supply functions. In addition, ASM also includes resource constraints that limit the regional supply of land, labor, and other factor inputs.

DATA

New Technology and Yields

The Mali ASM has a total of five sorghum production systems. The existing sorghum technology is a mix of traditional and improved production practices. Traditional practices include the use of local varieties, ridge tillage, and some manure to increase soil fertility. Improved practices include manure applications, ridge tillage to improve water retention, as well as improved varieties and inorganic fertilizers. The more intensive production scenario includes a more complete adoption of the improved production practices and varieties, and the adoption of two new varieties N'Tenimissa and Seguetana Cinzana.

Sorghum and millet yields for local and improved varieties for the Sudanian Zone and the Sudano-Guinean Zone are from Coulibaly (1995). These yield data were collected from different sources in Mali within the sorghum and millet breeding program. On-station, researcher managed trials and researcher managed on-farm trials and farming systems data were collected. On-station yields were reduced 25% and researcher managed on-farm yields were reduced 15% to account for better conditions on station for conducting experiments and better management (plowing, weeding, and harvesting on a timely basis) of researcher managed on-farm trials than farmers fields. Technology improvements were appraised in the Mali ASM by setting up different crop yields and cost of production versions of the model to provide simulation with and without the sorghum and pearl millet improvement technologies in Mali agriculture. The Mali ASM, upon solution, generates a wide range of information including estimates of regional and national agricultural commodity prices and quantities, input use, land use and crop mixes, and consumer and producer economic surpluses.

A biophysical model, EPIC, was used to estimate yields for the intervening period between 1997 and 2015. EPIC estimates soil erosion and tracks soil nutrient flows over time. Yields using traditional technology were found to have the largest yield decline, roughly .8 percent per year, and in general future yield estimates were consistent with a similar study in Mali (Dalton 1996). Significant reductions in yield declines were found when more intensive farming practices were employed.

Food Demand

The 2015 World Food Summit demand targets were forecasted based upon population growth projections, rural to urban migration, and assumptions on likely changes in consumer's income and food preferences. Projected food demands were done for both rural and urban households and were based on current per capita consumption patterns. The projections show about a 30 percent increase in rural demand, and a much larger increase in urban food demand of about 55 percent for sorghum and millet. Urban food demand increased significantly more due to higher future incomes, population growth, and rural to urban migration.

Adoption Rates

Given the scarcity of data on the adoption rates for the new sorghum technology, adoption figures were obtained from expert opinion and field experience. The adoption rates serve in the model as upper limits on the maximum number of farmers that could adopt; technologies are only adopted in the model provided that they are profitable (i.e. increase social welfare). Existing adoption rates of new sorghum and millet technology are estimated to be between 15 and 20 percent (Kergna 1998). Complete (maximum) adoption is given by a 50 percent adoption rate for the new technologies.

RESULTS AND DISCUSSIONS

Scenarios

In conducting the impact assessment, the Mali ASM was run under 1997 demand and supply conditions that reflected current levels of technology in crop and livestock production in each region. This was defined as the *Baseline* simulation. The current adoption rates were used to allow the systems to enter the base model simulation. In this manner, the economic impacts from fully adopting existing technologies can be separated from the expected potential benefits from new technology introduction. In the *Present* scenario, the new sorghum technologies are introduced into the model, and are allowed to compete with the local varieties being produced with the ridge tillage only. The *Year 2015* scenario considers future growth in demand that reflect projected population growth in both rural and urban areas. This is done with both existing and new technology. Finally, the *Maize* scenario considers an alternative new technology strategy, the introduction of new maize technology.

Baseline

The ASM model solution was compared to observed 1997 data to determine how well it corresponded to actual conditions in the Mali agricultural sector. Market prices and total production for the base model solution are close to the observed data for 1997, as shown in Table 1. For example, the prices of pearl millet and sorghum under the current adoption base model solution are within 2% of the observed prices in 1997. Production quantities for these two commodities were within 4% of observed levels. Prices and production quantities for the other commodities, in the base model solution are generally within 1% to 10% of observed values. Thus the base ASM solution corresponds fairly closely to current production quantities and prices for most major agricultural commodities in Mali.

Table 1 Sector Model Results: Commodity Prices, Production, and Consumer Demand

Item	Observed	Year 1997 Demand		Year 2015 Demand		
		Existing Technology	New Sorghum Technology	Existing Technology	New Sorghum Technology	New Maize Technology
Price (fcfa/kg)						
Millet	77	79	32	127	76	121
Sorghum	77	77	53	147	76	136
Maize	69	69	62	101	61	48
Production (000 ton)						
Millet	738	766	903	843	1,003	875
Sorghum	540	556	674	611	806	632
Maize	290	274	277	280	296	383
Total	1,568	1,596	1,854	1,734	2,105	1,890
Urban Demand (000 ton)						
Millet	-	227	364	279	352	294
Sorghum	-	356	474	445	552	463
Maize	-	87	90	94	135	193
Total		670	928	818	1,039	950

Present

Under existing demand conditions, the introduction of new technology results in dramatic price declines. The model predicts a complete adoption of the new sorghum and millet technologies up to the maximum adoption rates discussed above. As a result of the increased use of technology, sorghum prices would fall by about 59 percent as compared with current adoption, and millet prices would fall by about 31 percent (Table 1). Sorghum and millet production would increase by 137 and 118 thousand tons, respectively, corresponding to increases of 18 and 21 percent. Prices of maize would decline as production would be slightly increased.

With home consumption demands fixed near subsistence levels, the technology induced supply response for sorghum, millet, and maize would be absorbed by regional demand from consumers in the towns and urban areas. Clearly, for such large supply increases the demand for sorghum and millet is inadequate to maintain prices, as under existing demand sorghum and millet are primarily limited to staple foods with correspondingly low income and price demand elasticity. This explains the precipitous fall in food prices that accompanies technology introduction under existing demand conditions.

The national welfare components for the four scenarios are listed in Table 2. Consumers' surplus represents the Mali domestic consumers' surplus, and includes the home consumption value of the food produced and consumed on farms. Producers' surplus is the returns to land and labor resources of farmers. Farmers and their families benefit from both increases in returns to land and labor resources, as well as reductions in home consumption expenditures. Foreign surplus refers Mali's trade surplus, which is largely from cotton exports. Total social welfare is the summation of consumers' surplus, foreign surplus, and producers' surplus.

The analysis indicates that when current sorghum and pearl millet technologies are fully adopted under current 1997 demand conditions, consumers are the primary beneficiaries (Table 2). Urban consumers gain 19.6 billion fcfa[2] annually from the full adoption of the new technologies. This gain is distributed among the regions according to consuming population, with the largest share accruing to the capital city of Bamako. In contrast, producers experience a 45.7 billion fcfa annual reduction in the returns to their labor and land resources. However, much of this loss is offset by the 31.86 billion fcfa annual reduction in the home consumption expenditure that was included in the consumer surplus. Thus, the net loss to producers (i.e. rural households) is 13.84 billion fcfa.

Total social welfare in Mali increased 6.03 billion fcfa annually with full adoption of current sorghum and millet technologies under current 1997 demand conditions. These results indicate that current technologies when fully adopted and new cultivars being introduced may be expected to increase consumers' and national economic welfare, but reduce the economic welfare of farmers and their families in the aggregate.

[2] Since the fcfa devaluation in 1994, the average exchange rate has been around 500 fcfa = 1$.

Table 2 Sector Model Results: Welfare Measures

	Year 1997 Demand	Year 2015 Demand

Item	Existing Technology	New Sorghum Technology	Existing Technology	New Sorghum Technology	New Maize Technology
Consumer Surplus[a] (million fcfa)	764,457	816,026	852,047	1,051,502	956,144
		(+51,569)	(+87,590)	(+287,045)	(+191,687)
Producer Surplus[b] (million fcfa)	151,331	105,629	203458	220,035	211,873
		(-45,702)	(+52,127)	(+68,704)	(+60,542)
Foreign Surplus[c] (million fcfa)	6,818	7,006	6,576	5,596	6,336
		(+188)	(-242)	(-1,223)	(-482)
Social Welfare (million fcfa)	796,243	802,278 (6,035)	1,062,081 (265,838)	1,277,132 (480,889)	1,174,353 (378,110)

[a,b,c] Numbers in parentheses are the change in corresponding surplus relative to the existing technology case under 1997 demand conditions.

Year 2015

The current adoption base model solution is compared with the simulation reflecting existing and new technology introduction under projected 2015 demand conditions. Table 1 shows the results from the introduction of new sorghum and millet technology given the adoption rates discussed above. The model results indicate that with the new technology, the 2015 World Food Summit demand targets would be adequately achieved as indicated by the slight decline[3] in food prices. Sorghum and millet prices would fall slightly by 1 and 3 fcfa/kg, respectively, corresponding to declines of less than 3 percent.

To meet the projected 2015 demand targets, sorghum and millet production would need to increase by 250 and 237 thousand tons, respectively, or about 44 percent for sorghum and 30 percent for millet (Table 1). Home consumption for each of the cereal grains would increase about 31 percent by the 2015 target date, reaching a combined 1.135 million tons for sorghum, millet, and maize.

[3] If future food targets were not being adequately met, prices would rise significantly since food scarcity in the markets would bid up food prices.

A very different outcome emerges if new technology introduction was to stop, and technology was to remain fixed at existing levels out to the year 2015. All of the staple food prices would rise significantly, with sorghum experiencing the largest price increase. Sorghum prices would rise from 77 fcfa/kg to 147 fcfa/kg, corresponding to a 90 percent price increase. Millet prices would rise from 79 to 127 fcfa/kg, and maize prices would increase 69 to 101 fcfa/kg.

Producers have only limited ability to reallocate resources from non-staple food crop production such as peanuts and cowpeas, and the continued use of traditional technology results in yield declines from soil degradation as discussed above. As a result, aggregate staple food production would only increase modestly from 1997 levels under current technology conditions. Millet production would increase by about 10 percent from 766 to 843 thousand tons; sorghum by about 9 percent from 556 to 611 thousand tons; and maize by about 2 percent from 274 to 280 thousand tons.

With higher food prices, consumer's purchasing power is reduced, and urban demand falls to levels that are not much higher than 1997 demand levels. Urban demand for sorghum and millet would fall by 20 and 22 percent, respectively, if new technology were not introduced. This is likely to leave many consumers short of food subsistence needs, and suggests that satisfying the world food summit food targets[4] would be jeopardized by failing to introduce new technology.

The analysis indicates that when sorghum and millet technologies are introduced under the 2015 World Food Summit target demand, both domestic consumers and producers are beneficiaries. Consumers, including farmer's home consumption, gain 287 billion fcfa, of which 160 billion of this can be attributed to home consumption expenditures by farmers and their families. Producers' returns to land and labor are increased by 68 billion fcfa, resulting in a net welfare gain of 228 billion fcfa when combined with savings in home consumption expenditures. In contrast, foreign surplus declines as cotton exports are reduced by 1.2 billion as the increased food demand reallocates resources towards food production and slightly away from cotton production.

Total social welfare in Mali is increased by 481 billion fcfa under the 2015 demand growth scenario. These results emphasize the importance of assumptions about demand growth when economic impacts of new technologies are assessed in developing economies where agriculture is a dominant source of gross domestic product and employment.

If new sorghum technology were not introduced, then gains in consumer and producer surplus would be significantly lower. Consumer and producer surplus would only increase by 88 and 52 billion fcfa, respectively. Total social welfare would increase by only 266 billion fcfa, only about 56 percent of what social welfare would be if new technology were introduced.

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[4]The model used demand curves with fixed price elasticity. When high prices are encountered, aggregate demand falls appreciably, and quite likely below some consumer's subsistence level. An alternative would be to put a food subsistence constraint in for the urban households as was done for the rural households. See Vitale 2001.

Maize Scenario

The introduction of new maize technology would be much less effective in meeting the 2015 food targets. Although maize demand in the year 2015 would be adequately met, as indicated by the future maize price decline, sorghum and millet prices would increase substantially compared to their prices under the new sorghum technology alternative. Maize prices would fall from 61 to 48 fcfa/kg, but sorghum and millet prices would increase from about 76 fcfa/kg to 136 and 121 kg/ha, respectively. For sorghum and millet, there would be little change from the existing technology case.

While the percent increase in maize production is roughly the same as those for sorghum and millet, the larger production base for sorghum and millet explain why the aggregate benefits from new sorghum and millet technology are greater than maize. For instance, maize production would increase by about 40 percent, but this would correspond to an aggregate increase of only 109 thousand tons. Conversely, for sorghum a 44 percent increase would correspond to a 250 thousand ton increase, and for millet a 30 percent increase would correspond to a 237 thousand ton increase.

This aggregate effect also explains why the total social welfare change for the introduction of new maize technology is substantially lower than for new sorghum technology introduction. Total social welfare would increase by 378 billion fcfa, 20 percent lower than the increase in social welfare that would be generated if new technology were introduced in sorghum.

CONCLUSION

This paper demonstrated using ASM that new sorghum technology introduction has the potential to increase food production to levels sufficiently above those set by the 2015 World Food Summit targets. One clear message is that it will be necessary to improve cereal market infrastructure to jumpstart the process of technology introduction. Under present demand conditions, prices fall faster and advance more quickly than do the reductions in production cost brought forth by new technology. Benefits from intensification accrue only to consumers and only the very early adopters, and this threatens the process of new technology introduction towards the wider farming population. Thus, finding emerging markets for sorghum and millet will be important to promote the use of technology in the short to medium run.

While this paper presents optimism regarding new technology's potential to meet the 2015 food targets, it also presents an equal amount of pessimism if new technology introduction fails to materialize. Under existing technology, 2015 food targets would only be met with high food prices and the likely need for food aid. Such would be the case if the societies in the WAS were remiss in this intervening time before 2015, and entered the age of increased food demand using traditional technology. By then, continued land clearing of marginal lands is likely to result in significant environmental degradation. Efforts to intensify will be much less effective after the fact, will result in much larger societal costs in the long run, and will jeopardize future food security.

This means that the time to act would need to be now as far as establishing not only improved markets, but also in better developing input supply mechanisms. Although this paper did not focus on inputs, failure to keep production costs low as the process of technology diffusion process accelerates is vital. Kinks in the supply chains will result farmers bidding up input prices that would have similar effects to the fall in cereal prices that were documented in this paper. The new technologies will require that the seed manufacturing industry be ramped up, and assuring that rural vendors will have adequate access to inorganic fertilizer distributors to maintain inventory.

When new technology introduction was limited to maize, the 2015 food targets were only satisfied with high prices. Alternatively, new sorghum technology was found to provide higher societal impacts than new maize technology, and to result in a greater potential to increase food supply. The main advantage to sorghum would be from the larger production area since it is less demanding of soil nutrients and soil moisture. So, while the focus of development has often been on the semi-humid frontier, the drier sorghum and millet areas should not be overlooked when future food production is being considered.

This paper thus suggests that investments in sorghum and millet production should be maintained over the foreseeable future, and that sorghum and millet can be an integral part of strategies to assure that societies in WAS are able to satisfy the 2015 targets. In the sub-humid zones, sorghum and millet can maintain an important role in cotton and maize rotations, and here new varieties can be further refined to take advantage of a longer growing season. In the drier Sahelian areas, new technology gains in sorghum and millet might not be as impressive as with rice or maize, but the vast production areas are able to compensate for the more modest productivity gains.

The next modeling phase of this research will include a more detailed look into resource degradation, and how yields are likely to decline should traditional farm practices be pushed further out onto the frontier. A next generation erosion model, SWAN, will be used to better track the flow of soil carbon matter. This will bring into the analysis the importance of sequestering more carbon into the soils of the WAS, both for greenhouse gas mitigation as well as for more sustainable food production. In addition, the impacts from new technology introduction in sorghum and millet will be compared to those from rice and maize.

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From Conflict to Consensus: A Catalyst for Healthy Human, Economic and Ecologic Conditions[1]

Jeff Goebel[2]

ABSTRACT

Conflict resolution skills are taught to various participants of the SANREM/CRSP's Phase II program in Mali, West Africa. The premise of introducing these skills to participants is that unresolved conflict robs communities and institutions of vitality and opportunities to make rapid progress toward important goals and objectives. Appropriate conflict resolving processes can lead to consensual decisions of all involved parties, yielding behavior that is consistent with those agreements. This paper describes the methodology and consequences for bringing together the various stakeholders in the management of the bourgoutières, important riparian areas.

The conflict resolving process engages all conflicting parties in an atmosphere of respectful listening; allows the expression of concerns; and the fostering of desired outcomes. The participatory process is easily transferable, particularly when repetition is designed into the program. The workshops in Mali are designed around conflict resolution associated with various situations such as times of scarcity, and issues associated with power and control, change, and diversity. These skills are transferred directly to the participants and consequently capacity is built within the project. Key interest groups are villagers and herders living from the land; collaborating African agents, administrators, and scientists; and the array of US-based scholars, consultants, and institutions involved.

INTRODUCTION

Unresolved conflict robs communities and institutions of vitality and opportunities to make rapid progress toward important goals and objectives, including the research objectives of SANREM. Conflict resolution skills are taught to various participants of the SANREM/CRSP's Phase II program in Mali, West Africa. Appropriate conflict resolving processes can lead to consensual decisions of all involved parties, yielding behavior that is consistent with those agreements. Participants in this training include the Natural Resource Management Advisory Committee (NRMAC) representing village leaders, farmers and herders; NGO representatives, administrators, and scientists. This paper describes the methodology and consequences for bringing together the various stakeholders in the management of a bourgoutière, an important riparian area in the SANREM intervention zone. This methodology can be applied and tested in any conflict setting in which participants realize the value of confronting and successfully resolving conflicts.

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Case Study Questions:

1) What are effective tools for confronting and successfully resolving the conflict associated with the regeneration of bourgou?
2) What is the rationale for utilizing the tools?
3) What are the impacts of utilizing the tools?
4) What are the next steps to continue progress toward successful conflict resolution and consensus building for the management of bourgou regeneration and for the region?

A conflict resolution and consensus building process is being introduced to the Madiama Commune and associated SANREM partnerships. This experiential training addresses the process of conflict resolution and consensus building through various conflict venues. Basic conflict resolution skills are applied to intra personal, inter personal, and inter group conflicts. Various conflict venues include a basic introduction to conflict resolution, conflicts associated with scarce resources, conflicts associated with human dynamics and power relationships, conflicts associated with change and conflicts associated with embracing diversity. There is also a set of attitudes and behaviors associated with successful conflict resolution, which is being learned through modeling and practice of this process.

Over the last two years, three conflict resolution-training series were provided for the Madiama Commune NRMAC. The first series, in November 1999, involved a basic introduction to the conflict resolution process. The second part of this series involved the NRMAC members teaching what they learned to other villagers. The second series, in May 2000, addressed conflict resolution associated with scarce resources. The third series, in October 2001, focused on evaluation, conflict resolution associated with human power dynamics, and confronting and successfully resolving the bourgou regeneration issue. Each series was designed to bring a level of adoption of these skills, attitudes and behaviors to the NRMAC, building on the past trainings while discovering new venues of conflict resolution.

This region has a traditional conflict resolution process, which continues today. Currently, most NRM conflicts are resolved at the village level by the chief and his counselors. However, if the conflict is not settled at this level it will continue to the Chef d'arrondissement level (current pre-commune context), then the Justice Ministry at the Circle level (Djenne) or the regional authorities in Mopti. Madiama village leaders initially saw no areas for improvement in the conflict management strategies, despite a long-simmering conflict with the residents of nearby Nerekoro, a herder's village within the Madiama commune (Executive Summary PLLA, 1999). In Nerekoro, ideal NRM commune level decision-making would include: recognition of Nerekoro land tenure rights, Nerekoro-authorized natural resource use in their territory and the creation of a fair tax system relative to animal passage and potential damage caused by herds in fields.

Decentralization presents new problems and opportunities for conflict resolution. The SANREM West Africa project has brought together diverse representation from 10 villages and various backgrounds. Traditional village leadership recognizes these committee members as representatives for the villages. The following describes the status of conflict resolution activities drawn from a recent trip to Madiama and introduces the methods used to confront and successfully resolve the bourgou regeneration issue.

METHODOLOGIES

This paper describes two sets of tools introduced in the Madiama commune to help the NRMAC become successful in confronting and successfully resolving conflicts within and without the commune and the rationale for using these tools.

TOOLS USED

There are numerous tools used to foster confrontation and successful resolution of conflicts. Two sets of tools used in Madiama as a basis for conflict resolution and consensus building follow. Each set of tools has specific purposes. Clarity of purpose for each activity used during a conflict resolution session is important for fostering successful outcomes.

Set One Tools

Set One Tools are used to model effective behavior when striving for conflict resolution by creating a sense of potential equity and respectful listening.

1. The Grounding. An opening tool in which participants are seated in a circle of chairs and answer three questions, one person at a time around the circle. The three questions are: 1) Introduce yourself and your relationship to change?, 2) What are your expectations of this workshop? and 3) Tell us how you feel about being here. Participants are free to say as much as or as little as they want, and usually follow the lead of the first person.

2. The Greeting Circle: A Native American Adaptation. The Greeting Circle is a process to allow participants to introduce themselves directly to each individual in the meeting. The participants are standing and the Greeting Circle activity begins with a designated lead person. The lead person moves into the center of the circle and turns to the person next to him or her and greets them. The lead person moves on to the next person and so on around the circle. Meanwhile, the person first greeted also steeps into the center of the circle, and following the lead person, greets the next person in the circular line and continues greeting people around the circle. This continues until each person has gone around the inside of the circle greeting others, and the outside of the circle, being greeted.

3. An Adaptive Learning Process. Adaptive Learning occurs at the end of any enriching experience such as the Greeting Circle or at the end of the day. Again, one person at a time speaks, going around the circle answering two questions: 1) "How do you feel about the experience or situation?" and 2) "What did you learn from it that will make you successful?"

The Grounding, Greeting Circle, and Adaptive Learning are repeated throughout the workshop setting in order to:

- Establish a model for listening with respect, a knowing that each person will be heard.

- Establish a verbal territory for each participant, a sense of potential equity

- Facilitate access to both the left and the right brain, engaging the "whole brain.

- Allow apprehensions and hopes for the meeting to be expressed.

- Allow participants to express hidden agendas (manifested by, for example, leaving early; arriving late due to a flat tire; a sickness; etc.)

- Bring people into the "here and now"

- Provides initial information to the facilitator.

4. The Roles of the Successful Facilitator and Recorder. Often during the beginning of a workshop, the participants are allowed an opportunity to define successful roles. Again, continuing in a circle, one at a time, the following questions are asked and often recorded on newsprint: 1) "What is the role of a successful facilitator?" and "What is the role of a successful recorder?"

This process facilitates a sense of empowerment within the group as the facilitator models power sharing throughout the workshop. Such facilitator behaviors as allowing the participants to direct themselves, selecting participants to co-facilitate with the facilitator, and facilitating from outside the circle create a sense of equity within the group and further demonstrate the importance of empowerment. Allowing the participants to define their own concepts of successful facilitator and recorder roles creates a sense of self-direction. Throughout the workshop, all small group activities begin by selecting a new facilitator and the previous activity facilitator becomes the recorder. This models the importance of balance of being the powerful facilitator to being the submissive recorder. Balance of power is encouraged throughout the workshop and is modeled in such behaviors as having a representative from one ethnic group begin the workshop and a representative from another ethnic group close the workshop, or having a farmer and a herder or Mayor and NRMAC President serve on a panel. Panels are formed occasionally to begin the dialogue about specific conflict issues. Selecting powerful representatives or spokespeople from the various perspectives allows those individuals an opportunity to share their perceptions openly and feel listened to with respect.

As time allows, these activities develop listening skills and foster the importance of respectful listening among participants. The Grounding, Adaptive Learning, Defining Successful Roles and Defining the Worst/Best Possible Outcomes of a workshop allow ample opportunity to practice listening.

5. Worst/Best/Possibility. Another Step One tool is to allow the participants to explore and understand the importance of worst and best outcomes, and possibilities. The following two questions are asked: 1) "What are the worst possible outcomes of the workshop?" and 2) "What are the best possible outcomes of the workshop?"

This is important, particularly if the group is confronting a serious conflict. Also, allowing the group to express the worst/best outcomes of the workshop helps the group begin to understand the physiological patterns of humans with potentially threatening situations or issues.

Worst Outcomes: These are feared future outcomes, often based on past experience, with a presently experienced emotion and physical reaction. When people believe them, they affect their perceptions, beliefs, values and strategies. They tend to be self-fulfilling prophecies when strongly held.

Best Outcomes: These are hoped for future outcomes, sometimes not previously experienced, but intensely imagined, with a presently experienced emotion and physical response. When people believe them, they affect their perceptions, beliefs, values and strategies. They tend to be self-fulfilling prophecies when strongly held.

Possibility Thinking: An acknowledgment that both worst and best outcomes are present and inherent in each moment, up to, and often after the event. This balanced view allows the movement toward desired outcomes.

Set Two Tools - A Process for Coping with Conflict. The following set of questions are asked of the participants to develop an understanding of the conflict, concerns participants have for confronting the situation, defining their best outcomes and how to foster the best outcomes of the situation.

1. What is the situation? (Define conflict; What is the evidence of conflict in your environment?) How do I feel about it?

2. What are my worst outcomes of confronting/not confronting unresolved conflict?

3. What are my best outcomes of confronting and resolving conflict?

4. What beliefs/ behaviors/ strategies/ actions will foster the best outcomes?

Set Two Tools continue allowing participants to explore and understand the natural human response to potentially threatening situations and issues. The progression of questions noted above moves from developing a common understanding of the situation and the associated feelings, which qualifies the context of the situation in an emotional context. The second question explores the worst possible outcomes imagined of confronting the situation. These are the imagined reasons why confronting the issue is "dangerous". These reasons often paralyze individuals and groups into inaction. In that case, it's important to ask the other side of the question: "What is the worst possible outcome of NOT confronting the situation?" which allows groups to recognize the possible hopelessness of the other side of the question.

The worst possible outcomes response frees the group up to explore the possibilities of best possible outcomes of confronting a situation or issue. For most people, often paralyzed with the fear of confronting an issue; the possibility of fostering best possible outcomes of confronting a situation never arises. When people are allowed the opportunity to explore best possible outcomes, they begin to imagine ways to foster these outcomes. A sequence of two questions following the best possible outcome engages the problem solving nature of the human mind: "What beliefs and behaviors will foster the best possible outcomes?" and "What strategies and actions will foster the best possible outcomes?" Beliefs and behaviors focus on a fundamental transformational level change within people. Strategies and actions are focused on modificational change. Usually in conflict resolution, transformational change is required to move people to fostering the best possible outcomes of confronting conflict.

Step Two Tools allow participants to successfully move from a focus on worst possible outcomes to a focus on best possible outcomes as a distinct possibility. Often, allowing the group to explore conflict resolution at a generic level, before confronting real, and potentially threatening issues, provides the group with an understanding of the human behavior surrounding conflict resolution so they are more capable of successfully focusing on the issue. These tools are also helpful in developing a more complete understanding of the issue, particularly if diverse perspectives are involved. With this understanding and clarity of the best possible outcomes, the human mind goes to work to solve the problem of moving from the present to the desired outcomes of the group.

RESULTS AND DISCUSSION

What Conflict?

Results of the conflict resolution training activities so far have been promising. During the recent conflict resolution training in Madiama, the group posed the question "What conflict?" when the focus of the workshop was going to be confronting and successfully resolving the conflict associated with regeneration of the bourgou. This has been one of the most serious conflicts in the region. The group was suggesting that after two years and three conflict resolution and holistic management training sessions, they had a confidence in their ability to confront and successfully resolve this important issue. They had already begun devising successful strategies to resolve this issue. Their behavior reinforced the belief that they were indeed capable of resolving numerous issues because of the skills they now possessed.

The conflict resolution process is being incorporated into traditional conflict resolution processes in the Madiama commune. There is an acknowledged recognition in the region that negative conflict behavior is dissipating and a more respectful tone exists. Village leaders appear to be comfortable with the work of the NRMAC. The NRMAC is adapting the conflict resolution process to fit their needs by actions like specific methods for honoring community members. Another successful measure occurred during a recent training in which members of NRMAC taught the entire first day of a three-day workshop to resolve the bourgou regeneration issues. This training series was taught two years ago and the delivery was very complete. A movement is occurring in the region to expand this work to more communes in the surrounding region. As the process proves effective with the transhumant population, the opportunity exists for this process to extend across national boundaries.

The following is a list of the evidence illustrating that the best possible outcomes are already occurring in the Commune of Madiama developed by a group of local project leaders in Djenne, Mali, October 4, 2001. (Goebel, et al., 2001)

- Participation of the population in the search for greater control of the development process

- Establishment and reinforcement of the capacities of the NRMAC
- Several village level discussion meetings initiated by the NRMAC around the *bourgoutières*
- Good relations (Protocol of partnership) between the NRMAC and the Communal authorities
- Emergence of some community leaders with developing leadership skills
- Initiation of activities to regenerate natural resources (i.e., *bourgoutière* protocols)
- Signature of a protocol of partnership with CARE/Djenné
- Leaders putting community interests before individual interests (community spirit)
- Adoption of techniques diffused by research
- Utilization of radio programs for the diffusion of NRMAC information
- Definition of their own Goal - (See Appendix A)
- Mobilization of the internal resources (membership cards and contributions)

CONCLUSIONS

This method of conflict resolution is a consensus building process. The NRMAC appears to be effectively adopting and adapting this process at the local level. Members are finding applications of this conflict resolution process to aid in resolving real problems in a respectful manner. The NRMAC has matured over the last two years with the attitudes of consensus as demonstrated through their behaviors and results in the commune.

Is consensus always possible? No. If parties are not willing to explore solutions together, consensus is not possible. Is it even desired? It depends on the point of view? If you are the dominant one and are not bothered by other parties, why would one want to expend the extra effort? If you are in the submissive role and asking for a consensus agreement is life threatening, it may also be wiser to "go along" then try to force agreement. The conflict resolution process being taught in Madiama Commune is "a" process not "the" process. There are many successful methods to resolve conflict.

Future needs to strengthen this work include more reinforcement of the training on a more frequent basis. These training opportunities need to focus on modeling the confrontation and successful resolution of difficult community issues. The training needs to expand to the Commune leadership such as the traditional village leadership and discover methods to incorporate the transhumant population. Other opportunities to spread the training through the region, such as through CARE-

MALI, need to be developed. The next set of questions to build upon the work already occurring is:

1) Is this conflict resolving process effective in additional cultural settings?

2) What is the most effective method of delivering the training?

3) How will the process be adapted and institutionalized within the communities?

4) What will be the results for the community of institutionalizing the process?

5) What is the most effective method to transfer these skills to a greater region?

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Jeff Goebel, Moore, K., and Nadif, Ahmed. 2001. SANREM CRSP – West Africa Trip Report. October 1-18, 2001**Appendix A - The goal as defined by the NRMAC:**

Best Outcomes for a Strategy of the NRMAC

NRMAC Summary Statement

The development of the commune of Madiama is based on access to health and education. The strategy is based on the development responsibilities of the local population. The foundation of this strategy rests on a rational management of existing resources. The appropriation of new techniques, the adoption of various technologies and their adaptation to local conditions require greater control of the processes of production of consumer and material goods.

NRMAC Full Consensus Statement

The development of the commune of Madiama is based on access to health and education. *This involves a confidence in oneself, social cohesion and accords between the communities. To reach this situation, the NRMAC must completely control the mode of its operation. The operational control enables the committee to create many opportunities for conflict resolution and reduce the incidence of violent conflict. It is at this price that prosperity, happiness and health will reign in the villages.*
The strategy is based on the development responsibilities of the local population. *The communities must define their own goals to reach them with their own experience. In order to achieve this, the NRMAC must prioritize its needs and specify clear and precise objectives. The Process must begin step with step,*

initially by a good participation of the local community, development of a communication program, and monitoring of successful Community activities. To arrive at this level, it must make decisions without calling upon assistance. This can then become a model for the nation.

The foundation of this strategy rests on a rational management of existing resources. *The Community must develop methods and means allowing them to generate financial resources and to manage them. This will lead to stable soils and a rich ground cover, as well as an increasing water table. The landscape will then become rich in fauna, in flora, with water reservoirs and easy access to drinking water.*

The appropriation of new techniques, the adoption of various technologies and their adaptation to local conditions require greater control of the processes of production of consumer and material goods. *There is also a need for institutionalizing the marketing chain for income generating activities (AGR). This will build the commune's capacity to ensure its food self-sufficiency and to play a part in the national market.*

Policy And Technology Options For Dairy Systems In East Africa: Economic And Environmental Assessment[1]

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ABSTRACT

Assessment of smallholder dairy technology was used as a case study to develop models in the SANREM decision support system. Scenarios depicting the industry before current improvements, the current situation, and forecasted improvements resulting from further adoption of technology were evaluated. GIS methods were used to establish appropriate sampling frames for field studies and analysis. Forage and livestock models supplemented reported data as input to economic and environmental models. Assessment of the impact of alternative smallholder dairy technology packages was evaluated in the Sondu river basin using watershed models driven by economic and environmental models. With demand growth from projected population increases, full adoption of the improved dairy technology package would generate total economic welfare of KS 4,206 million. Full adoption of the technology package in the Sondu river basin would increase sediment loads in the basin by 5% over a 21-year period and stream flow would increase slightly. The general models developed from initial smallholder dairy studies predict annual increases in productivity of between 0.3 and 0.5% per year would be required to sustain food prices at current levels with 2015 demand. Intensification and extensification strategies were evaluated to achieve these levels of productivity. Combinations of strategies were predicted to be the most rational in meeting future food security demands with sustainable use of natural resources.

INTRODUCTION

The importance and contribution of livestock to agricultural production is well acknowledged. Winrock International (1992) reported that livestock accounted for about 25 per cent of agricultural gross domestic product in Africa in 1988. Animals are also recognized to be an important component of the process of intensification of agriculture under sub-Saharan Africa conditions. It is apparent that as population pressure increases, farmers find they must use more intensive technologies in order to increase livestock production.

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Over the past 20 years there has been a steady infusion of dairy technologies in East Africa by National Agricultural Research systems and Ministry of Agriculture programs in conjunction with international partners. As demand for milk has increased and markets improved, there has been an evolution of dairying. Dairy breeds have been introduced and used as crossbreeds or pure breeds, and improved forage varieties have been introduced. Several management and marketing practices, including improved animal health and the use of fertilizers to enhance forage production, have been made available. National research and extension programmes have contributed to the development and adoption of improved technology. The suite of technology include:

- Improved forages with multiple fertilizer levels.

- Improved strategic application of feedstuff/minerals, primarily corn bran, and commercial concentrate feeds and mineral sources, primarily phosphorus.

- Improved animal genetics by introducing pure dairy breeds, principally Friesian and Aryshire and infusion of these breeds in the local zebu cattle, primarily East African Zebu.

- Improved animal health programs for the introduced dairy breeds to minimize the impact of external and internal parasites.

- Intensification of production system through confinement of the animals part of the time (semi-zero grazing) or complete confinement (zero-based grazing) with infusion of various stall management technologies (shedding, floor construction, bedding techniques, composting, manure/urine management).

- Retaining and rearing of male calves up to 24 months of age for sale, primarily in extensive dairying situations.

The smallholder farms outweigh the large scale commercial farms, estates and ranches in importance in terms of numbers, land use and contribution to total output. In Kenya, an estimated 3,152 million kg of milk were produced in 1996. This production involved 9.8 million animals of which 7.7% were dairy breeds (principally Friesian and Aryshire), and 10.3% zebu x dairy crosses. The remainder of the dairy population was made up of a variety of zebu breeds, such as East African zebu, sahiwal and boran. The zebu breeds produce over 57.4% of the milk produced. Four main milk production systems are described in Table 1.

Table 1. Brief description of the four major small holder dairy milk production systems in Kenya.

Component	Zebu cattle grazing native/roadside/ plantation forage	Dairy x zebu cattle grazing native/roadside/ plantation forage	Dairy breed cattle grazing in semi-zero grazing	Dairy breed cattle with zero-grazing
Forage System	Kikuyu, stargrass, P. maximum, Themeda, other species, weeds, etc	Kikuyu, Stargrass, P. maximum, Themeda, other species, weeds, etc	Kikuyu, stargrass P.maximum, Themeda, other species, weeds, Plus Napiergrass or Rhodesgrass	Napiergrass or Rhodesgrass
Feeding system	Free or herded grazing	Free or herded grazing	Corral fed with limited tethered grazing or herding	Hand cut fodder in a corral/shed
Supplement	None	Minerals – 15 kg	Minerals – 25 kg concentrates – 450 kg	Minerals -25kg concentrates – 1000 kg
Disease control	None	Dipping	Dip and drench	Dip and Drench
Calf rearing method	3-7 month suckling	3-7 month suckling	16 wk whole milk bucket feeding	16 wk whole milk bucket feeding

The general approach of this of this study involved establishment of spatial framework, acquiring information and estimating missing data, parameterizing models, constructing sector models and testing possible scenarios. The methodology was tested in Kenya and extrapolated in Uganda and Tanzania, however this report addresses the process and outputs in Kenya.

METHODOLOGIES

Setting spatial frame

Environmental production sampling zones in Kenya were located spatially across the 6 dairy agro-ecological zones as identified by Jaetzold and Schmidt (1983). This ensured sampling of a range of environments making it possible for us to connect these traditional spatial resources to our digital spatial information system (Almanac Characterization Tool [ACT], Corbett et al. (1999)). From these zones we identified georeferenced smallholder dairy farms and we 'attached' characteristics of the environment data (edaphic and climatic variables such as annual maximum and minimum temperature, precipitation and potential evapotranspiration) contained in the foundation data in the Spatial Characterization Tool. Principle component analysis was carried out similar dairies were grouped into environmentally coherent groups (clusters). The dominant commodity-oriented dairy systems in the clusters were identified as, coastal, horticulture, coffee, tea, wheat and sheep zones. Using the spatial data in the ACT, we took these descriptions of the dairy groups and sought similar areas throughout Kenya thus converting a point description into a spatial characterization.
In order to support the agricultural sector analysis and on-farm economic analysis, representative households were defined for each of the identified commodity-oriented dairy systems. Initial

sampling frame depended on recent acquired spatial survey data. The key variables used in identification process were, farm size, land ownership, Napier grass acreage, maize acreage, number of cattle, number of dairy animals, number of indigenous cattle, predominant genotype/breeds, feeding/grazing system, distance from trading centre/market, house hold size, value of concentrate purchased, value of fodder purchased, milk production per day per cow, soil type, rainfall, altitude, mean daily temperature and household income. Principle component analysis was carried out on these variables and a multiple regression equation was established between dairy system and the other farm variables using the stepwise method (SAS, 1987). The CHART procedure (SAS, 1987) was then used on each of the principle components with uniform classes by farming system. Histograms were developed which also gave information such as frequency and percentage for each class. The midpoint (class) percentages were noted, and households with a value of the variable within the class were assigned the midpoint percentage and a sum of all the percentages of variables made. The representative farm selected (median farm) was the one with the highest total percentage score from all the variables derived from the principle components.

Once the representative farm was selected, detail location of the farm was sought and the enumerator involved in the data collection identified and contacted and the farmer interviewed. Each farm's herd structure was weighted according to the proportion of each production zone in a province to create an average herd structure by province to help serve needs in the Agricultural Sector Model.

Computing biophysical inputs for agricultural sector model

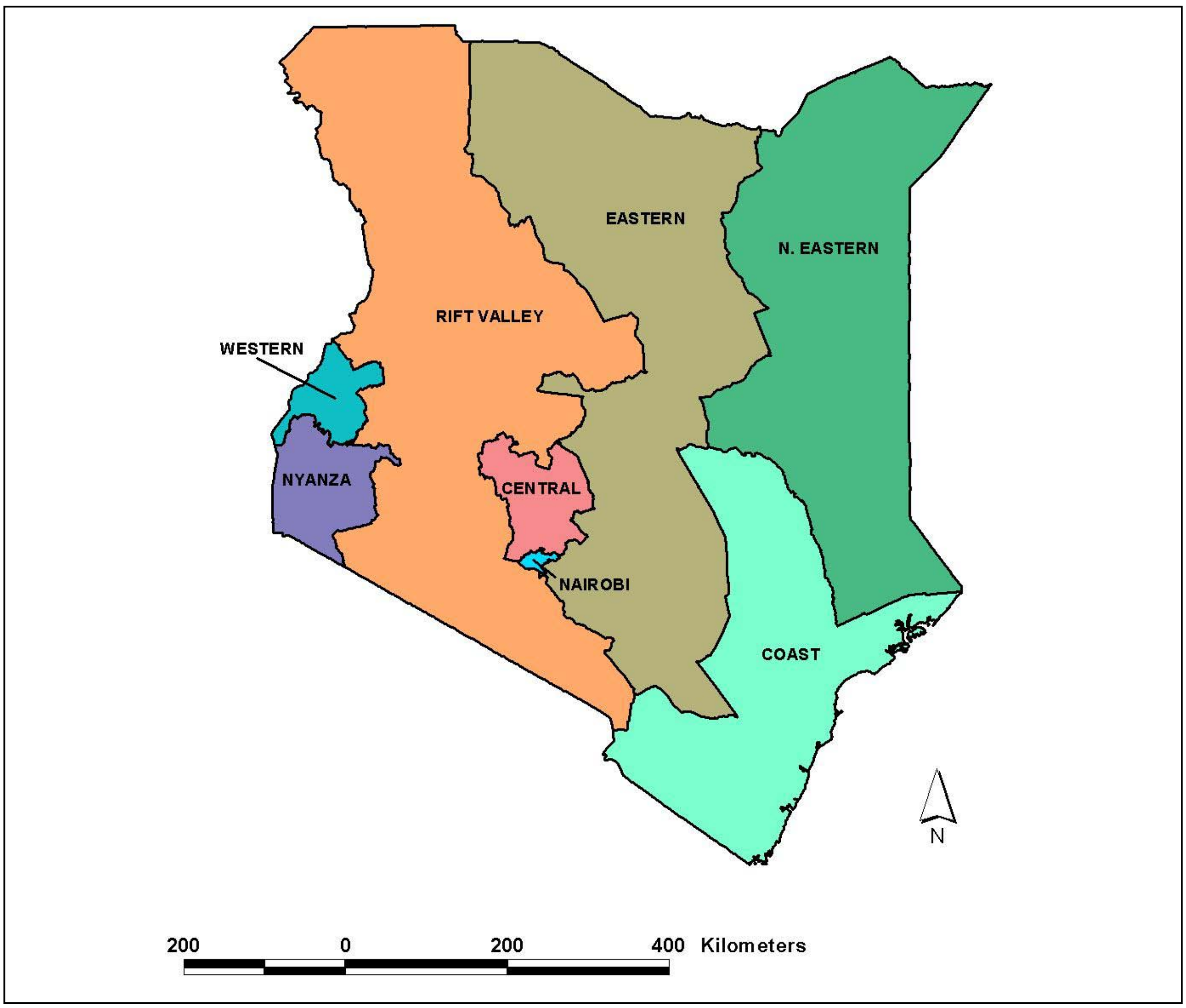
Agricultural Sector Model (ASM) is an equilibrium sectoral economics model used to conduct national and sub-national level analyses of price, production, consumption, and foreign trade responses to technology and policy by state of nature across multiple regions, farm produced commodities, and processed products. The ASM requires definition of the categories of animals within production systems, average annual yields of crops and supporting forage sources, annual nutrient requirements in terms of protein and energy, annual milk production, and annual nutrient requirement of cow units (protein, energy, intake).

Representing a composite or average view of the various production systems by administrative boundary proved challenging, given the constraints of data reporting for Kenya's livestock industry. It was decided to use seven provincial regions in Kenya for which economic and biophysical data was applied. The North Eastern province was dropped from the analysis because it represented neither an agricultural production nor a demand region (Figure 1).

To derive mean requirements and milk yield by livestock production system in each province, first a "typical herd structure" of each of the production systems in each province was determined and then the requirements of the herd per cow unit in that herd derived. The NUTBAL PRO Nutritional Balance Analyzer model (Stuth et al. 1999) was used to compute the annual requirements for crude protein, net energy of maintenance, and intake demand of the animals by breed type, class, and production system. The weighted herd structure for smallholder dairy households in each province based on the composition of the production types delineated in the study was used to define the animal classes and breed types for each province.

Once location and numbers for each of the breeds had been established, average monthly profiles were derived for each production system based on environmental conditions (derived from the ACT analysis), average nutritional values, terrain conditions, feed inputs, and potential intake restrictions. The average monthly values were run as a case for each class of animal for an entire year. The resulting monthly values were placed in an ACCESS database and assigned weighted values based on the mean herd structure for each province and production system. The weighted monthly values were then summed into annual requirements for crude protein (kg), net energy of maintenance (mcal), and intake (kg). Values for the milk cow component were on a cow unit basis. To reflect the steer fattening operations, annual requirements were derived for a 12-24 month and 24-36 month steer summed for annual production. The rangeland herd was derived based on studies of herd structure conducted by Peeler and Omore (1997).

The ASM input requires that forage resources be characterized in terms of average annual yield (kg/ha), crude protein content (%), and net energy concentration (mcal/kg) by province. Forage/ fodder resources were categorized as maize stover, Napier grass, native forage, purchased fodder, and concentrate feed for smallholder dairy. To account for beef production in the ASM system, a



rangeland component was added to the matrix. Yield values were derived from area-weighted estimates based on yields of crops generated

Figure 1. Provinces of Kenya

from the EPIC model and forage yields from the PHYGROW model using the household surveys of the representative farms conducted for each production zone adjusted to the provincial expected yields. Resulting yields were used to develop spatially synchronized yield probabilities needed for economic risk analysis in ASM. Forage intake by animal class and expected milk yield were generated from these diet-quality values and weather data using the NUTBAL PRO nutritional balance analyzer. A simple spreadsheet program called LAND DEMAND was created to help compute the supporting land area for the herds by provincial level identified for the agricultural sector analysis.

The Kenya Agricultural Sector Model

In Kenya ASM, the market is assumed competitive and equilibrium price and quantity are determined by the intersection of supply and demand for each commodity. Many consumers and producers are assumed to be in the competitive market. Consumers maximize their utility subject to budget constraints. Similarly, producers maximize their profit given production technology and prices; therefore, the supply function depends on prices and technology. Aggregation of each consumer demand function and each producer supply function results in market demand and supply functions. In this competitive market, social welfare is maximized when the market is in equilibrium. That is, maximum welfare will occur at the intersection of the demand and supply function. ASM includes market balance constraints and resource constraints and assumes that maximizing social welfare is the objective function. The model generates estimates of agricultural commodity prices and quantities, input use, land use and crop mixes, and consumer and producer economic surpluses.

As mentioned earlier, the Kenya ASM considered seven of the eight geographical provinces that include the Nairobi, Central, Coast, Eastern, Nyanza, Rift Valley, North Eastern, and Western regions (Figure 1). Nairobi was treated as a demand only province, and the North Eastern province is neither an agricultural production nor demand region in the Kenya ASM. The other six regions have both demand and agricultural production activities. The Kenya ASM also includes inputs on the production of 18 primary products and 9 secondary products (Table 2).

Table 2. Primary and Secondary Products in the Kenya ASM.

Primary Products		Secondary Products
Wheat	Maize	Coffee
Maize residue	Sorghum	Tea
Millet	Beans	Milk
Potatoes	Groundnuts	Pork
Raw coffee	Raw tea	Beef
Raw milk	Bull calves	Mutton/goat meat
Cull cows	Heifers	Net energy maintenance
Sheep/goats	Baconers	Crude protein
Napier grass	Native grass	Dry matter

Crop production is defined by province and agricultural zone. Livestock production activity is by province, animal type, and agricultural zone. Major crops modeled in the Kenya ASM are maize, millet, beans, wheat, sorghum, coffee, and tea. The major livestock enterprise modeled is dairy cattle;

however, beef, sheep, and hogs are also modeled. Agricultural zones depict crop growth and yield potential of land and climate resources and are designated as high, middle, and low zones. Labor and land are used in the crop and livestock production activities and are limited in quantity by production region.

Commodity demand in the Kenya ASM depicts three market levels: home consumption expenditures, regional markets, and international trade. Technology improvements are evaluated by setting up different forage, animal management systems, cost of production, and associated technology adoption versions of the model to provide simulations with and without the smallholder dairy intensification technologies in Kenya agriculture. Simulation results for each technology and adoption scenario are compared to evaluate the economic impact of the technology on regional, national, and foreign consumers and producers. Current and full adoption rates for the dairy production systems are included in simulations in order to estimate past and potential economic impacts.

Current adoption rates are defined as the percentage of herds in each province using the technologies defined by the management system alternatives; the current adoption rates represent the existing mix of traditional and improved dairy production systems. Full adoption rates represent best judgments of the maximum percentages of herds using the improved dairy production systems after wide-scale introduction of the technologies. Current adoption rates for the dairy production systems were obtained from survey data from Omore et al., (1999). We consulted with experts who had experience conducting studies of adoption profiles to estimate the full adoption rates. Experts provided information on adoption profiles for the animal breed, forage and feeding, and health components of the dairy production systems.

GRAPHIC DESCRIPTION OF THE MODEL

Figure 2 shows supply and demand curves and illustrates the potential impact of technology adoption. Assume there exists aggregated demand and supply curves for a commodity in Kenya, as D Kenya and S Kenya . Also assume there is export of the commodity from Kenya to the rest of world (ROW). The excess supply curve ES Kenya is calculated from the aggregated supply curve minus the aggregated demand curve. With an improved technology that is implemented into the production system, assume the aggregated supply curve shifts from S Kenya to S' Kenya. The domestic production and export quantity increase while the domestic price decreases When the improved technology is adopted.

Consumers' surplus, producers' surplus, and foreign surplus also are changed due to adoption of the technology. Domestic consumers' surplus will increase as shown by the area of A while the change in producers' surplus will be the area of (E+D-B-A) when the improved technology is adopted. The producers' gain or loss depends on the sign of (E+D-B-A). Foreign surplus also changes as the area of (G-F). The Kenya ASM estimates these changes in consumers' surplus, producers' surplus, and foreign surplus from shifts in the milk supply resulting from the adoption of smallholder dairy technologies.

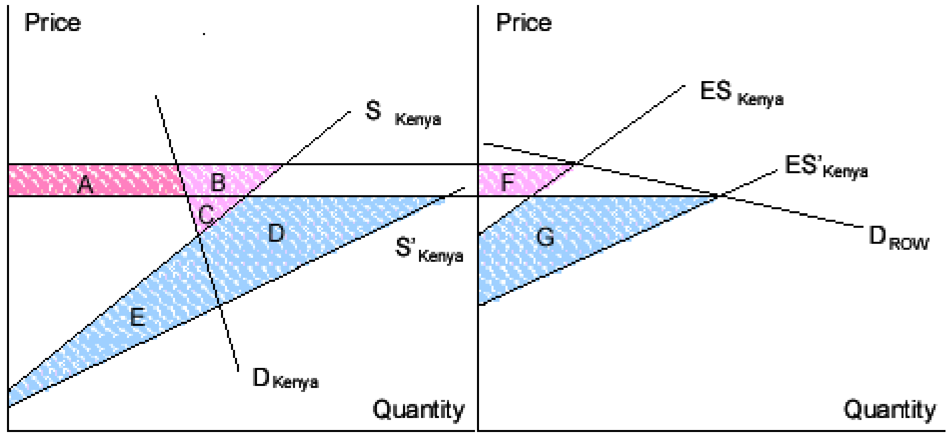


Figure 2. Welfare changes under alternative production technology in an open market.

To verify the output of the ASM, the outputs such as market prices, total production, exports, and imports for the current dairy production in Kenya were compared to observed baseline data. The base model, designated by the baseline data reflecting the current economy, was defined as improved dairy technology under current adoption rates.

ASM analysis compared results from the improved dairy technology under current adoption to the results from the traditional dairy scenarios. The improved dairy scenario allowed all the current dairy production technologies to enter the ASM solution. The current adoption rates for systems 2, 3 and 4 as shown in Table 3 limit the mix of these technologies in the simulation. The traditional dairy scenario allows only the zebu cattle dairy production technology to be used to meet current demand. The results of this comparison showed the past impact of technology adoption.

Improved dairy technology under current adoption was compared to the improved dairy technology under full adoption rates. Price, production, input use, and welfare components were compared in the following economic impact assessments. This comparison showed the potential impact of expanded technology adoption. Estimates of current and future adoption rates were made using a panel of national research and extension experts.

RESULTS OF THE ASM: PRICE AND PRODUCTION

Results of the ASM showed that improved dairy technology has had a positive effect on the Kenyan economy and social welfare. Further positive impacts are possible under a full adoption scenario, although the bulk of the benefits has already been achieved given current demand. As population increases, demand will be created. Future improvement in dairy production is most likely to meet the growing demand.

If current demands had to be met with traditional dairy technology rather than improved dairy technology under current adoption rates, the raw milk price would be 16.31Ksh/kg, which is 6.1% higher, as shown in Table 4. The quantity of raw milk produced would be down by 48.5%. Regional demand for milk in the urban areas of Kenya would drop by some 58 thousand tons and the deficit supply for milk would have to be met with increased imports, totaling some 1.58 million tons with an import price of 18 Ksh/kg (Tables 4 and 5). The burden of the price increase for raw milk would fall primarily on home consumption by farmers and their families. Price, production, and regional demand for other commodities would not be significantly affected. The major change in commodity production and price would be a 7.9% decrease in wheat production with a corresponding 2.17% price increase.

Regional milk production would decrease if the Traditional Dairy technology was currently in use to produce all milk and provincial shifts in wheat, maize, millet, and bean production also would be expected. The Rift Valley and Nyanza provinces would experience increases in maize and bean production while the Western province would have decreases in production of these two crops. Thus, one result of the development and adoption of the improved dairy technologies has been to foster these changes in land use and crop production.

Table 3. The definition of dairy cattle technology and adoption rates for the animal breed/feed/management system alternatives.

Scenarios	Allowed dairy production technology	Allowed sources for feed
Improved dairy current adoption	Zebu-cattle, (1) Cross breed cattle, (2) Dairy breed cattle with semi zero-grazing, (3) Dairy breed cattle with zero-grazing. (4)	Napier grass maize residue native grass
Traditional dairy	Zebu-cattle (1)	Maize residue native grass
Improved dairy full adoption	Zebu-cattle, (1) Cross breed cattle, (2) Dairy breed cattle with semi zero-grazing, (3) Dairy breed cattle with zero-grazing. (4)	Napier grass maize residue native grass

Cattle Breed/ Feeding * \ Province	Current adoption (%) **				Full adoption (%) **			
	1	2	3	4	1	2	3	4
Central	5	5	20	70	0	0	20	80
Coast	75	10	10	5	60	15	15	10
Eastern	50	10	20	20	30	15	25	30
Nyanza	75	10	10	5	40	15	20	25
Rift Valley	50	5	15	30	30	10	25	35
Western	80	10	5	5	40	25	10	25

* The proportion of dairy breed/feeding system (1) representing the traditional zebu breed of cattle with grazing of native grass and feeding of maize residues is allowed to enter the ASM algorithm at 100% with the numbers for the dairy technology systems 2, 3, and 4 constrained to zero percentages for each region under the traditional dairy scenario.

** Defined as the percent of total animals in dairy herds using the technologies defined by the animal breed/feed/management system alternatives. Full adoption represents the maximum percentage of total animals in dairy herds that would use animal breed/feed/management systems 2, 3 and 4.

Table 4. Milk price, production, import and export under 18 Ksh import milk price in the Kenya ASM.

Unit: Ksh/kg, ton, million Ksh

Scenario	Price	Production	Import	Export	Welfare
With 18 Ksh/kg import price					
Improved dairy current adoption	15.37	3729172	36365	36365	201967
Traditional dairy	16.31	1918101	1616774	36365	199083
Improved dairy full adoption	15.05	3742136	36365	36365	202672

The improved dairy current adoption scenario resulted in an estimated 285 thousand fewer number of cows required to produce the raw milk to satisfy total demand compared to the traditional dairy scenario. Dairy cows numbers in the Central and Rift Valley provinces were 408,323 and 1,124,878 head, respectively, under the improved dairy current adoption scenario. Under the traditional dairy scenario, the Central province would have been required to increase cows by 67% to produce sufficient milk to meet current demand. The Rift Valley province would have 1,072,526 dairy cows, a 4% decrease in cow numbers. The Eastern and Western provinces would experience increases in cow numbers by 95.2% and 30.0%, respectively, while the Coast and Nyanza provinces would reduce cow numbers by 31.5% and 88.2%, respectively.

If full adoption conditions existed, given the current 1995 demands for the commodities, raw milk production would be increased an additional 12.9 thousand tons and the price of raw milk would be reduced 2.0%. Wheat production would be decreased by 5.4 thousand tons with a corresponding increase in price of 0.34 Ksh/kg. Provincial consumers in the urban areas would increase their consumption of the additional amounts of milk. Under the improved dairy full adoption scenario, total cow numbers would be expected to decrease in the Central (24.4%), Eastern (17.3%), Rift Valley (41%), and Western (37.8%) provinces, while increasing substantially in the Coast (243.2%) and Nyanza (25.3%) provinces.

CHANGES IN LABOR AND CROP LAND INPUTS

Labor and crop land usage (Table 5) shows that the changes in labor and crop land use varies among regions and between the dairy technology scenarios. Both labor and crop land use would be lower under the traditional dairy scenario as compared with the improved dairy current adoption scenario. Full adoption conditions for the improved dairy technologies would reduce both labor and crop land usage from the current adoption scenario.

WELFARE EFFECTS

Producers' surplus would be 0.5 billion Ksh, or 7.4%, less annually if Kenya were dependent on the traditional dairy technologies (Table 5). The increase in price for the commodities would not offset the reduction in quantities produced, resulting in a slight decrease in total returns to farmer and family labor and land. Producers in most regions would experience a decrease in returns to these resources; however, producers in the Eastern province would have 15 million Ksh more income annually. Home consumption expenditures would be higher in each region under the traditional dairy technologies. For Kenya as a whole, these expenditures would be an additional 2.24 billion Ksh or 4.1%, annually. When the change in producer surplus and home consumption expenditures are combined, a measure of the net economic benefits to farmers and their families from the improved dairy technology is obtained. The improved dairy technologies under current adoption conditions resulted in 2.74 billion Ksh annual net gain to producers and their families.). If Kenya relied solely on traditional dairy technologies to meet current demands, total social welfare in Kenya would be decreased 2.883 billion Ksh, or 1.43%, annually (Table 6). Most of the reduction in social welfare would result from substantially increased imports of milk.

Table 5. Regional land and labor usage, producers and consumer's surplus, and home consumption expenditure in the Kenya ASM.

Item by Province	Improved dairy current adoption	Traditional dairy		Improved dairy full adoption	
		Change	Percentage	Change	Percentage
	(Value)	(Value)	(%)	(Value)	(%)
Labor (1000 man days)					
Central	82775	3991	4.82	-5734	-6.93
Coast	15155	-4106	-27.09	25138	165.87
Eastern	71000	930	1.31	0	0
Nyanza	132770	-11775	-8.87	5462	4.11
Rift Valley	200718	-17753	-8.84	-27417	-13.66
Western	67062	-1538	-2.29	1570	2.34
Crop land (1000 ha)					
Central	746.49	-17.35	-2.32	-14.53	-1.95
Coast	796.00	0	0	132.71	16.67
Eastern	3769.87	-573.59	-15.22	169.67	4.50
Nyanza	1252.01	0	0	0	0
Rift Valley	2527.33	-465.27	-18.41	-539.40	-21.34
Western	3354.81	31.67	0.94	-39.47	-1.18
Producers' surplus (million Ksh)					
Central	602	-21	-3.44	-115	-19.07
Coast	14	-17	-117.53	127	900.00
Eastern	112	15	13.02	4	3.97
Nyanza	4068	-25	-0.62	1	0.02
Rift Valley	1664	-420	-25.22	-524	-31.50
Western	301	-32	-10.64	0	0
Home-consumption expenditure (million Ksh)					
Central	-10907	-700	6.42	-12	0.11
Coast	-2012	-93	4.64	25	-1.24
Eastern	-6362	-300	4.72	4	-0.06
Nyanza	-4597	-208	4.52	82	-1.79
Rift Valley	-28029	-866	3.09	535	-1.91
Western	-2561	-77	3.00	9	-0.34
Consumers' surplus (million Ksh)					
Nairobi	45239	-231	-0.51	-44	-0.10
Central	18778	-194	-1.03	6	0.03
Coast	6995	-23	-0.33	28	0.40
Eastern	19380	37	0.19	32	0.16
Nyanza	14252	39	0.28	104	0.73
Rift Valley	47965	-132	-0.23	37	0.08
Western	7807	47	0.60	16	0.21

Full adoption of the improved dairy technologies would result in a net economic gain to producers and their families in Kenya. Producers' surplus would decrease 506 million Ksh annually but home consumption expenditures would decrease 642 million Ksh annually, or 1.18% annually, resulting in a net annual economic gain of 136 million Ksh (Table 6). With the adoption of the improved dairy technologies, total social welfare increased an additional 2884 million Ksh annually. These results indicate that the improved dairy technologies have substantially benefited producers and their families through expanded supplies and lower prices for milk and other commodities and through reduced milk imports. The results also indicate that when the improved dairy technologies are fully adopted, consumers' and national economic welfare would be further increased, but farmers and their families would realize only modest gains in their economic benefits. Reductions in the returns to land and labor resources would be nearly equal additional savings in home consumption expenditures for rural people.

Table 6. Welfare comparison under alternative scenarios with 18 Ksh/kg milk import price.

Unit: Million Ksh, %

Welfare measure	Improved dairy current adoption	Traditional dairy	Improved dairy full adoption
Consumers' surplus	160416	159959 (-0.29)	160596 (0.11)
Foreign surplus	89260	89578 (0.36)	89651 (0.44)
Producers' surplus	6761	6262 (-7.39)	6255 (-7.49)
Home consumption expenditure	-54471	-56716 (4.12)	-53829 (-1.18)
Total social welfare	201967	199083 (-1.43)	202672 (0.35)

ECONOMIC IMPACTS OF ALTERNATIVE DAIRY PRODUCTION SYSTEMS UNDER FUTURE DEMAND GROWTH CONDITIONS (2015)

The improved dairy current adoption base model solution were compared with the simulation reflecting full adoption of existing dairy production technologies under projected 2015 demand conditions. Population projections to year 2015 in urban and rural areas within each province of Kenya were used to project food demands by commodity. Projected food demands for farmer and family home-consumption and domestic regional consumers in towns and cities by province were based on current per capita consumption rates for each commodity by province and place of residence, i.e. rural or urban.

PRICE AND PRODUCTION

Wheat and millet prices increase 17.6% and 19.0%, respectively. All other commodity prices are within 1.0% to 6.0% of base 1995 price levels. Raw milk price decreases 0.9 Ksh/kg, or 5.86%. Corresponding increases in production quantities of 438.7 and 40.5 thousand tons, or about 695.0% for wheat and 74.0% for millet, respectively, would be required to meet projected demand levels. Milk production would increase 1.41 million tons, or some 117.0% to meet future demands by regional consumers in towns and cities and home-consumption by farmers and their families. Home consumption for cereal grains, potatoes, and groundnuts would near double. Milk consumption by farmers and their families would increase 113.0%. Domestic regional consumption would more than double for wheat, maize, potatoes and groundnuts, and increase 68.0% and 85.0%, respectively, for sorghum and millet. Quantity of milk consumed by regional domestic consumers would increase 117.0%. Yield increases to meet projected 2015 demands at near 1995 price levels would need to average about 0.3% to 0.5% per year for maize, potatoes, sorghum and raw milk. Yields for beans and raw coffee would need to increase about 0.9% annually, while beef and millet yields would need to grow at a 2.5% annual rate. Groundnut yields would need to increase near 4.5% per year, while wheat yield would require an annual growth rate of 6.25% to meet 2015 projected demands at near 1995 price levels.

WELFARE EFFECTS

When the dairy technology improvements are fully adopted under demand growth rates associated only with rising population for the next 15 years, as contrasted to current adoption rates and demand levels, both consumers and producers are beneficiaries. Regional consumers in towns and cities nationally gain 181.54 billion Ksh (113.2%) annually, while home consumption expenditure by farmers and their families is increased 58.3 billion Ksh (107.0%) annually. Producers return to land and labor are increased 11.8 billion Ksh each year. The increase in home consumption expenditure for food substantially outweighs the increase in producers return to land and labor. Foreign surplus increases only slightly, up 274 million Ksh annually, or about 0.3%. Total social welfare in Kenya is increased 135.31 billion Ksh (67.0%) annually under the demand growth scenario. Increased production and consumption of milk accounts for near one-third of the increase in welfare of regional consumers in towns and cities, and about 72.0% of the increase in home consumption expenditures of farmers and their families. These results indicate that even under demand growth conditions, domestic consumers in towns and cities are likely to be the major beneficiaries of the smallholder dairy research and technology transfer relative to rural producers and their families that adopt the new technologies and increase the available domestic supply of milk.

CONCLUSIONS

Improved dairy technology had a positive effect on the Kenyan economy and social welfare by substantially benefiting producers and their families through expanded supplies and lower prices for milk and other commodities and through reduced milk imports. The results also indicate that when the improved dairy technologies are fully adopted, consumers and national economic welfare would be increased, but farmers and their families would realize only modest gains in their economic benefits. Reductions in the returns to land and labor resources would be nearly equal additional savings in home consumption expenditures for rural people.

When the dairy technology improvements are fully adopted under demand growth rates associated only with rising population for the next 15 years, as contrasted to current adoption rates and demand levels, both consumers and producers benefit. The increase in home consumption expenditure for food substantially outweighs the increase in producer's return to land and labor. Increased production and consumption of milk accounts for near one-third of the increase in welfare of regional consumers in towns and cities, and about 72% of the increase in home consumption expenditures of farmers and their families. These results indicate that even under demand growth conditions, domestic consumers in towns and cities are likely to be the major beneficiaries of the smallholder dairy research and technology transfer relative to rural producers and their families that adopt the new technologies and increase the available domestic supply of milk.

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Priorities of Stakeholder Decision Makers

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ABSTRACT

While land users directly manage natural resources, decisions made at local, provincial, national, regional, and global levels directly and indirectly influence agriculture and natural resource management. Relationships and perceptions among different stakeholder groups within and among each of these levels are important to informed decision making that can influence our natural resource base and the future of sustainable agriculture. SANREM has been fortunate enough to play a role in several fora that have provided a venue for the issues and opportunities of divergent voices related to sustainable agriculture and natural resources management to be shared and exchanged. These include global electronic conferences, electronic discussions, and face-to-face multistakeholder dialogues. Although clearly not a comprehensive study, the purpose of this paper is to draw on key ideas that have emerged from these fora to provide insights into the SANREM Phase III planning process.

INTRODUCTION

This paper draws on decision maker priorities that have evolved through multistakeholder dialogues and e-conferences in collaboration with the Food and Agriculture Organization and the International Partners for Sustainable Agriculture on topics of food security, the multifunctional character of agriculture, sustainable agriculture and rural development, and land planning and management. Additionally, a SANREM e-discussion was held in preparation for the conference to which this paper is being presented.

The key research interest is an understanding of different decision maker priorities as indicated by which sector they represent as well as at which decision making level they are working or making a livelihood. This paper summarizes several findings from these various

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venues. The world is preparing for Rio+10, the World Summit on Sustainable

Development, to be held in South Africa in 2002 and the SANREM CRSP program is simultaneously preparing for its next phase of activities. The purpose of this paper is to bring issues raised by different stakeholders to bear in guiding the design of SANREM CRSP Phase III.

METHODOLOGIES

The SANREM CRSP in collaboration with the Food and Agriculture Organization (FAO) and in several instances with the International Partners in Sustainable Agriculture (IPSA) have engaged in multiple electronic discussions and stakeholder dialogues. These included:

- *Cultivating our Futures: The Multifunctional Character of Agriculture and Land* (1999) brought together over 1200 electronic participants from civil society, public and private sector to address the importance of the multiple roles that agriculture plays in our society and how to assess the importance of operationalizing these aspects of Sustainable Agriculture. A series of electronic conferences led to the Dutch funded face-to-face conference in Maastricht, Netherlands that was also accessed via a web forum by the e-participants.
- *Broadening the Research Horizon: Integrating sustainable food security dimensions into the National Agricultural Research Agenda* (2000). Two electronic consultations brought together over 400 individuals from the public and civil society sectors to discuss key priority research issues related to food security.
- *SARD Forum, preparing for Rio+10 and the FAO Committee on Agriculture* (2001). Working with the Task Managers of Chapters 14 and 10 of Agenda 21 in preparation for the World Summit on Sustainable Agriculture (WSSD) and the Committee on Agriculture SARD Forum, key representatives of the major groups of Agenda 21 (Indigenous Peoples, Business and Industry, Nongovernmental Organizations, Trade Workers, and Farmers) participated in an discussion board, followed by an electronic conference (400 individuals) and a face-to-face multistakeholder dialogue held in conjunction with the Committee on Agriculture in FAO, Rome.
- *Multistakeholder Consultation on Food, Agriculture and Land Resources for the 2002 World Summit on Sustainable Development* (2001) In preparation for the World Summit on Sustainable Development (Johannesburg, September 2002), the first of a series of US citizens' preparatory multistakeholder dialogues on the issues of food security, sustainable agriculture and rural development (SARD) and land resources was held. US government representatives heard views of representatives of the major groups of Farmers, Trade Workers, Business and Industry, Scientists, and NGOs to take forward in official preparations at national, regional and international levels.

Although not comprehensive, this paper draws out some of the key issues that divergent stakeholder decision makers find to be priority areas for sustainable agriculture and natural resources management that resulted from these venues. In addition, the outcome of the Multistakeholder Dialogue held at the Commission on Sustainable Development's 8th Session (CSD-8) focusing on agriculture and land, documents from WSSD regional preparatory conferences completed prior to this writing, an e-discussion of the SANREM research partners and interviews carried out in the Philippines, Mali and the Southern Piedmont of the United States through the SANREM CRSP Assessment of Decision Maker

Priorities project. This paper focuses on issues related to sustainable agriculture and research and development.

The responses are shown according to the major group from which the individual or group was speaking. These major groups are based on those identified in Agenda 21. Included in this are representatives of Business and Industry, Farmers, Indigenous Peoples, Non Government Organizations, Science and Technology and Trade Unions and Agricultural Workers. In some cases, the contributions come from representatives of major groups that have utilized the input of numerous colleagues to make their input. In other cases, an individual from one of the major groups has made the contribution.

RESULTS AND DISCUSSION

Many issues were raised in the context of the various venues described. We have chosen to identify these according to categories of Resource Management, Livelihoods, and Policy. Within each of the categories, we provide a list of issues raised by different stakeholders or decision makers. Following the issues list is a brief description of perceptions by representatives of Business and Industry, Farmers, Indigenous Peoples, Non Government Organizations, Science and Technology and Trade Unions and Workers on aspects of the issues.

Resource Management

Table 1. Issues Related to Resource Management

Resource Management	
Biodiversity Conservation Agricultural Biodiversity	Soil Conservation Conservation Technologies Land Degradation
Agroecological Practices Organic Agriculture Integrated Farming Systems Integrated Livestock and Crop Management Integrated Pesticide Management Appropriate Technologies	Farmland Conversion Habitat Maintenance Green Space Conservation Agroforestry Fisheries Watershed Management
Participatory Land Management Land Use Decision Making Conflict over Resources	Water Quality and Quantity Air Quality Status of Land Resources
Climate Variability Awareness of Links between Ag and Environment Ecosystem Services and Valuation Agricultural	Health, Food Safety, Labor, and Environment Standards Health Impacts of High-Input Agriculture Lack of Strong Research Base
Waste Management Alternative Energy Sources	Extensification/intensification Biotechnology

Within resource management, the following are discussion points that center on aspects of integrated and sustainable farming systems.

Business and Industry view increasing agricultural production per unit area of agricultural land, identifying locally adapted and integrated farming practices as the most appropriate method of sustainable agriculture. Integrated farming systems are based on best practice principles that seek to employ the most appropriate mixture of modern and traditional methods to achieve productivity, efficiency and economy, while providing the social and environmental benefits sought by society. Industry representatives highlighted the potential positive social impacts of biotechnology.

Farmers representing the views of a broad spectrum of countries identified that the most important resource for SARD is the farmer and should be recognized as a producer and a citizen within her or his community. Farmers are concerned with the present agricultural production systems and the trend towards more intensive and industrial agricultural production. There are clearly uncertainties surrounding genetically modified organisms (GMOs). Land tenure was identified as a prerequisite of sustainable farming.
Farmers stressed the importance of shifting the focus of international agricultural strategies from corporate-driven food production to the small-scale family farmer. Reviving and regeneration of traditional genetic resources will improve biodiversity in agricultural production systems.

Although *Indigenous Peoples* represent only 5% of the world's populations, 90% of world's cultural diversity, about 80% of the world's remaining biodiversity is within their territories. They spoke to the importance of appropriate technology and the rehabilitation of organic systems and agroecology. The maintenance of cultural and spiritual relationships to the natural world, our lands, and our subsistence foods is vital to the conservation of the biodiversity. They asked for the translation of container directions on agro-chemicals to the languages of countries to which they are exported.

Non-governmental organizations stated that the best practices for sustainable agriculture are first and foremost local expressions and are those that are ecologically based – stating that conventional agriculture (intensive uses of agrochemicals and monocropping) is inherently unsustainable. On individual stated that "the green revolution technologies have become 'islands of success' in a 'sea of deprivation'" The high input, energy intensive, corporate style agriculture is not only non-remunerative to farmers but will further erode the fragile ecosystem, natural resources and aggravate rural poverty. They noted that genetically modified organisms posed actual and potential hazards that would undermine agricultural biodiversity and compromise the rights of consumers. One participant noted that the opinions of scientists on GMOs differed widely, and that a moratorium should be put in place until a consensus and further research on their possible effects could be realized**.** They suggested that farming systems that were not based on purchased inputs were unattractive to private agri-businesses subsequently not supported by them.

Science and Technology representatives noted that agricultural advances often bypass small farmers and that trends of biotechnology are enhancing monocultures and further industrialization of agriculture. There are many examples of farmer-led and NGO led agroecological initiatives that have resulted in enhanced food security and environmental conservation regeneration. Recent data gathered by Jules Pretty at Essex demonstrates that more than 9 million households have used agroecological approaches regenerating about 29 million hectares throughout the developing world. Research should aim at developing mixed farming systems that integrate annual crops with perennial crops, livestock and trees, and emphasis soil fertility management, organic matter, moisture conservation, erosion control, and nutrient recycling. Agroforestry, intercropping and organic farming as well as the rehabilitation of traditional foods are important. The focus should be on increasing yields of crops that form a large part of poor peoples' diet and income.

Trade unions and workers identified waged agricultural workforce as untapped, skilled workforce with generations of knowledge on food production and the food system. Participation by workers in decision-making on all aspects of food production is not being promoted. They noted that training in integrated pest management would clearly serve as an alternative to using hazardous pesticides ensure the recognition of their role and contribution – past, present and future - to SARD

There was general agreement that the diversity of the world's farming systems called for a variety of technologies and approaches. A few comments from *Government* representatives noted that there is a crisis in prevailing agricultural models in developed and developing countries. There is the further need for diversification of agricultural systems. They pointed to the importance of conservation of genetic resources and the recent problems of animal health and food safety.

Livelihoods

Table 2. Issues Related to Livelihoods

Livelihoods	
Market Opportunities Improved Farmer Income Improved Community Revenues Food Prices Agricultural Risks Farm Economy and Regulations Promoting diversified enterprises	Food Security Food Safety Production Access to Food Access to Land Non Destructive Livelihood Scenarios
Empowerment for Informed Choices for Farmers Institutional capacity at different levels to design, negotiate plans that benefit population Wage Workers and Labor Standards Contract Farming	Losses of Rural Society Opposing stakeholders Interface of local and scientific understanding

Business and Industry felt that market-oriented approaches that stimulate entrepreneurship and facilitate economic growth are the means by which to promote sustainable agriculture. Increased market opportunities can foster sustainability for farmers. Partnerships between public and private industries were cited as one way to use technology to enhance social development.

Farmers presented the case of women in the agriculture sector and proposed that conversion to sustainable agriculture should be a gradual process with support mechanisms put in place for the farmers, particularly women, engaged in this change process. Access to credit would be critical for small farmers and title to land is essential as collateral for credit. Farmers need market opportunities. This means fair prices for their products and a more level playing field for their trade. Without remunerative prices farmers cannot invest in the best agricultural methods for sustainable agriculture. Programs to provide farmers with secure tenure are important.

Indigenous Peoples suffer from a lack of food security and income. Access to credit and strengthening organizational capacity are called for. It is important that they can strengthen their own *in situ* systems of registering and protecting traditional knowledge; the recognition of self-determination and the collective ownership rights to lands territories and natural resources. Historical prejudices have lead to the systematic exclusion of what people need to live a dignified life.

Non Government Organizations identified security of land tenure as the basis of food security. Land reform was seen as a means to address the inequities in land tenure patterns and enable broad-based economic development by creating local markets. One individual noted that local private voluntary efforts of farmers and allied civil society groups started with little policy or public agency support.

Science and Technology argued that pressure for cheap food production has caused unreliable farm incomes, pressures on small-scale producers, reduced food security, concerns over food safety, loss of competitiveness for third-world producers, problems for animal welfare and environmental damage. Despite increases in food production, food insecurity is linked to massive poverty, poor distribution of land, and the pressures of globalization that emphasize agro exports away from basic food crops. One colleague raised the issue of developing "sustainable food habits". Building an awareness of value of local resources and products can help eliminate the ideology that what comes from developed countries must be good because the citizens have higher standards of living. Short term goals, inadequate funding, lack of inclusivity, ties with Agribusiness, lack of local orientation, lack of education and infrastructural support and lack of political have limited our progress.

Trade unions identified the importance of agricultural labor standards to promote sustainable employment and employment condition. Waged agricultural workers and their trade unions can play a greater role in food safety and food security issues.

Some comments from *Government* recognized the impact of low prices for agricultural goods, placing the viability of small farmers and national agricultural systems in peril. The need to increase farmer income and offer new economic opportunities, or face increasing poverty and unemployment was indicated. A developing-country delegate noted that, while for developed countries sustainable development might be a matter of lifestyle, for developing countries it was primarily a matter of livelihood.

Policy

Table 3. Issues Related to Policy

Policy	
Political and Economic Stability Monitoring International Agreements Multi-sectoral Cooperation Decentralization Legal instruments for the sustainable use of natural resources	Policy related to income distribution and food demand increase Policy Analysis of market prices and incentives Tools to evaluate changes in land management practices relative to agricultural investments Supporting farmers to reduce pollution
Effective Participation on all policy making levels Participatory Planning Processes Support for decentralized management of natural resources and sustainable land use Policy Advocacy and Farmers' Organizations	Overcoming conflicting governing bodies – harmonizing multiple agendas Lack of coherence between national and local policies
Public Support for Agriculture Research Increased information for decision making	Secure Land Tenure and Land Reform Rural and Urban Biases Inconsistency with electoral transitions

Business and Industry proposed policies that would align food prices, dismantle government price support systems, promote trade and investment in the agri-business sector, and harmonize control systems. In order to build an enabling framework to attract financial resources for sustainable agriculture, needed are political and economic stability, inclusiveness, accountability and good governance.

Farmers noted that agriculture does not operate in isolation but is affected by the constraints and aspirations of the society that surrounded it. They stated that peasants and small-scale farmers were traditionally under-represented in decision-making related to agricultural production. With regard to getting at sound trade regimes, farmers identified the following as key components: a stable policy environment, adequate rural infrastructure, an appropriate regulatory framework, effective stakeholder participation mechanisms, increased resources for development, and improvements in technology transfer mechanisms.

Indigenous peoples also called for effective participation on all policy-making levels along with the democratization of financial institutions. Indigenous Peoples carry diverse traditional knowledge and practices that are threatened by globalization. Representatives expressed concern over national laws that allowed the unhampered exploitation of their lands and territories.

Non Government Organizations noted that a major threat to sustainable agriculture was unbridled trade liberalization. Agricultural policy designs tend to be dominated by the powerfully linked interests of industry, urban markets and trade. Rather than enhancing sustainable development, globalization caused subsidies and cheap imports that have subsequently undermined local productivity. Organizations called for a reassessment and examination of the true impact of globalization on social, ecological, technological and economic grounds. They noted that international forces (e.g. governments and UN bodies) have prevented and precluded the establishment of such important programs that develop the capacity of these many people to improve their lives and to encourage them to participate in the growth and development of their countries and of the world economy. Affluent countries have never willingly carried out actions that infringe upon the standard of living of their populations. True partnerships among stakeholders require confronting major challenges such as access to land and the forces of globalization, especially trade policy and prices for exported raw materials. Such forces undermine sustainable agriculture making family farmers, indigenous peoples, rural women and other stakeholders ill prepared to collaborate with governments.

Science and Technology noted that Globalization has intensified problems associated with policies that have inadvertently increased poverty and increased environmental degradation. Poverty, population growth, natural resource depletion and environmental degradation are linked in a vicious cycle. Representatives called upon the United Nations to provide the political support for an alternative agricultural development approach, engaging in a real partnership with NGOs, farmers organizations, environmental groups and consumer groups in the search for a more socially just and economically viable agriculture.

Trade unions promoting the international acceptance of core agricultural labor standards as a central component and measure of sustainable agriculture given the growing impact of multinational corporations. They emphasized the need for trade and investment regimes to promote the social dimension of sustainable development. Current patterns of control and distribution were the most pressing issues and stated that the rules must be changed that govern trade and investments that widen gaps between the rich and the poor.

MEETING THE CHALLENGE WITH RESEARCH, EDUCATION AND TECHNOLOGY TRANSFER

Because Research, Education and Technology Transfer are used to address the issues identified above related to Resource Management, Livelihoods, and Policy, we do not present an extended list of issues. Rather, we focus on stakeholder perceptions of the priorities related to what is needed in the context of research, education and technology transfer.

Business and Industry representatives said that good agricultural practices require continued investments in research and development in the agro-food industry and integrated management approaches that can improve efficient use of seeds, nutrients and resources. Agribusiness has increasingly taken up research and development activities since there has been a decline in public investments and the need for productivity increases. They recognized education, training, information and extension activities as being necessary for comprehensive knowledge and sustainable food systems. Sustained relationships between stakeholders are important for achieving SARD. They promoted empowering farmers to make informed choices and stated that education and training are important tools to allow communities to develop appropriate solutions at the local level. Participatory models of knowledge transfer and joint problem solving are the most likely approaches to create lasting solutions adapted to local conditions. Speaking to the development of new technologies, they emphasized the need for additional research and the right to choose from technologies which are accepted or rejected based on sound science rather than emotional reaction.

Farmers stressed that research must be farmer-driven and built on traditional knowledge. An increase in public sector funding and available resources was called for to support farmer-to-farmer cooperation, extension programs and information centers. Farmers noted that skills building is required to make a successful career in farming by choice rather than lack of options. Training should support and enhance traditional practices. Without strong, representative organizations, farmers are unequal players. Farmers should establish relationships with all levels of government, from the community level up to the international level. Partnerships are needed between farmers' organizations, research institutes, and consumers' organizations. Farmers' groups were skeptical about partnerships with multinational companies in the agro-food sector.

Indigenous Peoples suggested that indigenous knowledge and science can work hand in hand. If knowledge is power, it is important to avoid using information to benefit specific interests of science while marginalizing small farmers. To link science and traditional knowledge, there was strong support for increased focus on intellectual property rights, indigenous rights, protection of indigenous cultures, and new codes of conduct. Indigenous peoples' representatives proposed the use of their education programs, founded on their cosmovisions, as models for sustainable food systems. They noted a willingness to work with non-indigenous partners on issues related to food safety, culture, environment, genetic resource erosion, and intellectual property rights issues and stated that all partnerships must be based on equality.

Non-governmental organizations acknowledged that training, education, research and capacity-building needs, including their cultural and spiritual dimensions, must be approached and supported in a holistic way. This effort must recognize the central role of farmers (farmer-driven agricultural research) and indigenous peoples in research and development. It was suggested that it will be critical to develop education and information policies to disseminate knowledge of sustainable food systems and their relationship to food security to raise awareness of consumers and other non-farmer stakeholders. One NGO noted that all of the research has already been done, over the last 30 years pretty much all of the solutions have been devised and tested - what is holding back implementation of sustainable agriculture is the lack of political will, and the surplus of consumer ignorance and apathy. Human dignity and participation remains unaddressed. Research and development targeting needs of men and women and small-scale farmers, and in support of indigenous knowledge are seen as essential. Research and development must be able to deliver site-specific solutions and increased funding is required for research on ecological approaches to farm management.

Science and Technology asked that government find ways through international cooperation to enhance rather than decrease the numbers of research and development institutes in the agricultural sector and sustainable development. One researcher commented that institutional research capacity remains weak, government support is low, and donor support is capricious and suggested regional initiatives to meet the challenge. The most immediate challenge is to develop and mobilize cutting edge science and disseminate information relevant to limited resource farmers and their constraints. This means "changing practices, revisiting traditions and empowering farmers". It was suggested that it is more important to extend meaningful knowledge complemented by information about the ways it is generated, so that techniques can be replicated according to local conditions. Science wants to improve technology to increase production often forgetting that the technology is unaffordable to limited resource farmers. Contract farming has diminished the capacity for farmers to work in a participatory fashion with researchers. A joint effort and greater emphasis on interdisciplinarity is required to raise efficiency of production, enhance quality and productivity of resources, ensure protection of forests and natural habitats, maintain biodiversity and minimize the adverse effects of climate variability, especially on fragile areas. Technology transfer to limited-resource farmers still requires extension services that are often weak in many developing countries. In some cases, the only active outreach is done by the chemical input industry that is focused on marketing products. Measures to strengthen technology transfer and diffusion through the encouragement of local innovation and technological development are needed and environmental measures should not be used by developed countries as new protectionist measures. It will be necessary to restore a different kind of resources management ethic based on social and ecological values and on global and holistic perspectives through educational programs. One researcher identified that research challenges demand appropriate technologies that are: 1) based on indigenous knowledge or rationale; 2) economically viable, accessible and based on local resources; 3) environmentally sound, socially and culturally sensitive; 4) risk averse, adapted to farmer circumstances; 5) Enhance total farm productivity and stability.

Trade Unions and Agriculture Workers asked for expanded education and training programs to include training in sustainable agriculture. Linkages with small farmers' organizations and trade unions were seen to enhance sustainable agriculture.

In response to some of these suggestions, a few *Government* representatives emphasized the need for training of farmers and local leadership to achieve a "multiplying effect" in rural areas as well as the need for capacity and institution building of civil society in various national contexts, in part to better represent their constituencies, make empowerment effective and build genuine partnerships amongst all actors. They noted the importance of dialogue, with each partner keeping their end of the bargain, and arriving at a common level of information and language for fruitful discussion and to work together harmoniously.

CONCLUSIONS

Through the ideas drawn upon for this paper, it is evident that there are similarities among the stakeholder opinions, both in terms of the issues as well as the proposed solutions, but there are also differences both subtle and less so.

As an example, all stakeholder groups saw partnerships as important to sustainable agriculture, however they viewed them differently. Business and Industry cited partnerships between public and private industries as a means to enhance social development, while NGOs acknowledge that true partnerships among stakeholders require confronting challenges such as access to land, policies, and globalization. Representatives of Science and Technology state that true partnership must be developed among NGOs, farmers' organizations, environmental groups, and consumers in order to have a more sustainable and equitable agriculture. Farmers identify themselves as the key resource in sustainable agriculture and indicated skepticism about partnerships with multinational companies. Indigenous Peoples showed a willingness to work with non indigenous partners in order to better sensitize them to their concerns. Trade unions saw the value of working in partnership with farmers' organizations. Several stakeholder groups indicated that the partnerships must be "true" and "equal". On the other hand, in the case of biotechnology and trade liberalization, greater differences among stakeholder perceptions were apparent.

Most of these fora took place at a global scale and subsequently more broad-brush issues were raised. A number of these fora included stakeholders speaking in front of governments and subsequently it was rarely a dialogue with government. When designing research and development projects it is important to engage all stakeholders at all levels in the decision making hierarchy. To address this, SANREM has developed an interview protocol to assess different priorities of different stakeholders at the local, provincial, national and regional levels. This protocol entitled "assessment of decision maker priorities" has been tested in the Philippines, Mali, Ecuador and in the Southeastern United States. Designing research and development activities using global fora and more in depth assessments should ensure that our work continues to be demand driven and provide meaningful input to participatory and informed decision making.

Electronic Conferences and face-to-face multistakeholder dialogues have provided new and important venues for capturing the insights of the many voices that influence and are influenced by sustainable agriculture and natural resources as well as allowing for the exchange of ideas and the debate of proposed solutions. It is important that these avenues of information exchange serve to inform demand driven research and development as well as participatory decision-making.

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Common Modeling Environment (CME): A Framework for Integrated Decision Support Systems[1]

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ABSTRACT

Assessing impact of technologies and policies requires the use of a suite of decision support models that address the complexity of economic systems at the sector level, farm level economics and human welfare, crop production, grazing land production, livestock performance and resulting environmental processes. Typically "integration" of these processes involved manual transfer of data files between applications or limited digital integration in a subset of modules. Further, there was limited ability to modify models in a manner that allowed tighter "digital" integration. There is growing need within SANREM and with other partners, including FAO, to package a number of different research simulations together to develop a more detailed and holistic view of non-homogeneous activities and environments. This need to package integrated suites of models so that they can be run on a single computer or internet/intranet, led to the pursuit of the Common Modeling Environment (CME) concept. CME is an evolving set of information technology that is modular and designed to grow in sophistication as needs are identified within organizations. This system brings cross-platform delivery, a scalable distributed computing model, and shared common input data to many research models with minimal model modification. A model server process can be run on any platform that has a *JAVA* virtual machine installed and quickly allows incorporation of stand alone models without undue stress on research model developers.

INTRODUCTION

A primary problem facing policy analysts in today's decision environment is the need to use a wide variety of economical, sociological, biophysical and environmental models in a coordinated manner that allows a rational sequence of analyses to represent the complexity facing the decision maker. Models represent a long-term investment by their developers to properly represent complex relationships in an evolutionary process of verification, upgrade knowledge and validation cycling as new technologies allow enhancements throughout the development profile. Model developers are reluctant to change their finely tuned models to accommodate a broader set of analysis; thereby, creating problems of data sharing and transfer between model input/output. This has given rise to loose coupling of models to avoid inter-dependency between models.

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Over the past 10 years a large number of decision support tools have been designed to address a wide array of economic, biophysical, spatial, demographic, social and natural resource issues affecting sustainable development of societies throughout the world. These computer-based tools are designed with a specific set of data needs, targeted toward a specific user group using a unique set of computer development tools and database environments.

Many of the analytical environments associated with such issues as food security, sustainable development, climate change, desertification and biodiversity require a suite of tools to be used to address emerging issues given the complexity of problems associated with these issues (Meehl et al. 2000). Typically, a minimum set of analyses involves some form of economic analysis supported with one or more biophysical models. These suites of models are generally referred to as "loosely coupled" (Yourdon and Constantine 1979) in that data from one model is moved in digital form after the output had been modified to fit data structures of the receiving model, typically moving such things as crop yields to economic farm models with the acreage determined with GIS tools such as ARCVIEW. As you increase "coupling" of models in a digital sense the complexity of parameterization increases but strength of system feedback also increases.

Clearly, coupling or integration of models to address a broad range of development issues must keep a clear focus on such issues as availability of data to support the use of the models, skills levels of the targeted users, training needed to effectively use the models, institutional commitment to use of the analytical systems and the sustainability of personnel to use those models. Often the call is made for much more simple models with low data requirements, resulting in low level coupling and requiring special care to capture the right data output to feed input of other models needed to address a more complex development issue. However, most of the more difficult issues in development are complex, requiring complex analytical tools to explore possible interventions, technologies or policies (Britton 2001).

Impact assessment (IA) of new technologies and policies that address such issues as food security and natural resource management have a strong spatial component, a representation of multiple resources of land use (cropland, grazing land, livestock) in biophysical models and multi-scale economic analyses addressing farm, community, national and regional issues. The impact assessment group (IAG) has been developing methodology under the umbrella of a global decision support system for impact assessment in the SANREM CRSP over the past three years. The IAG suite of tools currently uses three spatial tools (ACT 3.0, ARCVIEW, ERDAS), a statistical package (SPSS), several biophysical models (SWAN, PHYGROW, NUTBAL PRO, SWAT), a series of small utilities (WXGEN, LANDDEMAND, CURVE EXPERT, etc) and several economic models (ASM, FLAM, FLIPSIM).

Clearly, this suite of tools is not designed for an inexperienced person to use, even with the appropriate discipline training such as agricultural economics, agronomy, animal science or rangeland management. The question arises: "how do we capture the analysis and package that analysis in a manner that is usable by those technical staff that support analysis by decision makers that effectuate policy or choices of technology funding"?

In order to address this issue, a concept referred to as the "Common Modeling Environment" or CME was pursued by IAG. The goal of CME is to provide an information technology development environment that can accommodate a wide variety of models in a manner where the developer of the model defines the level of interaction with their modeling environment without any changes in the design of the application. CME also is designed to allow the model developer to define those variables a user can change and rerun the model. The goal of the CME is to develop a middleware language (Britton 2001) that allows the packaging of a suite of pre-parameterized models that reflect the legacy analysis of a given impact assessment project and defines those selected variables that an inexperienced person could "tweak" to explore additional analyses without additional training or capacity building within a targeted organization. To address this concern, a web-based common modeling environment is being developed to allow a variety of models to be presented for use in a cohesive manner.

This ambitious objective has been pursued for the past few years of SANREM to a point where a new generation of tools can be made available to modelers interested in delivery of their analysis in a more controlled analytical environment. The CME concept is evolving with new features constantly added to the middleware language to expand features of the system. The evolving middleware language in CME is targeted for use by the model developer while the interface, once defined by the modeling team, is targeted to the primary user group of the suite of tools.

This paper focuses on the technical issues underlying CME and provides a framework for system that can be used to set up models for use by inexperienced users. Initial funding for CME was provided to the Center for Natural Resource Information Technology via the Texas Agricultural Experiment Station. However, recently the FAO World Agricultural Information Center (WAICENT) has also provided funds along with the SANREM CRSP to design inputs to the CME concept to help create a mechanism to deliver a wide variety of analytical tools to their partners throughout the developing world.

METHODOLOGIES

The CME concept originally grew from the recurring situation of needing to package a number of different research simulations together to develop a more detailed and realistic view of non-homogeneous activities and environments. The CME structure is comprised of a browser enabled interface, CME client, CME server, model factory, resident databases, and remote databases/models/GIS tools (figure 1).

Browser Enabled Interface

One initial concern of CME is to develop an interface that is intuitive to use by non-modelers. To address this concern, a web-based common modeling environment is being developed to allow a variety of models to be presented for use in a cohesive manner. A common user interface for model configuration and results analysis decreases the model configuration learning time and makes cross model comparisons and aggregations quick and easy. This system brings cross platform delivery, a scalable distributed computing model, and shared common input data to many research models with minimal model modification.

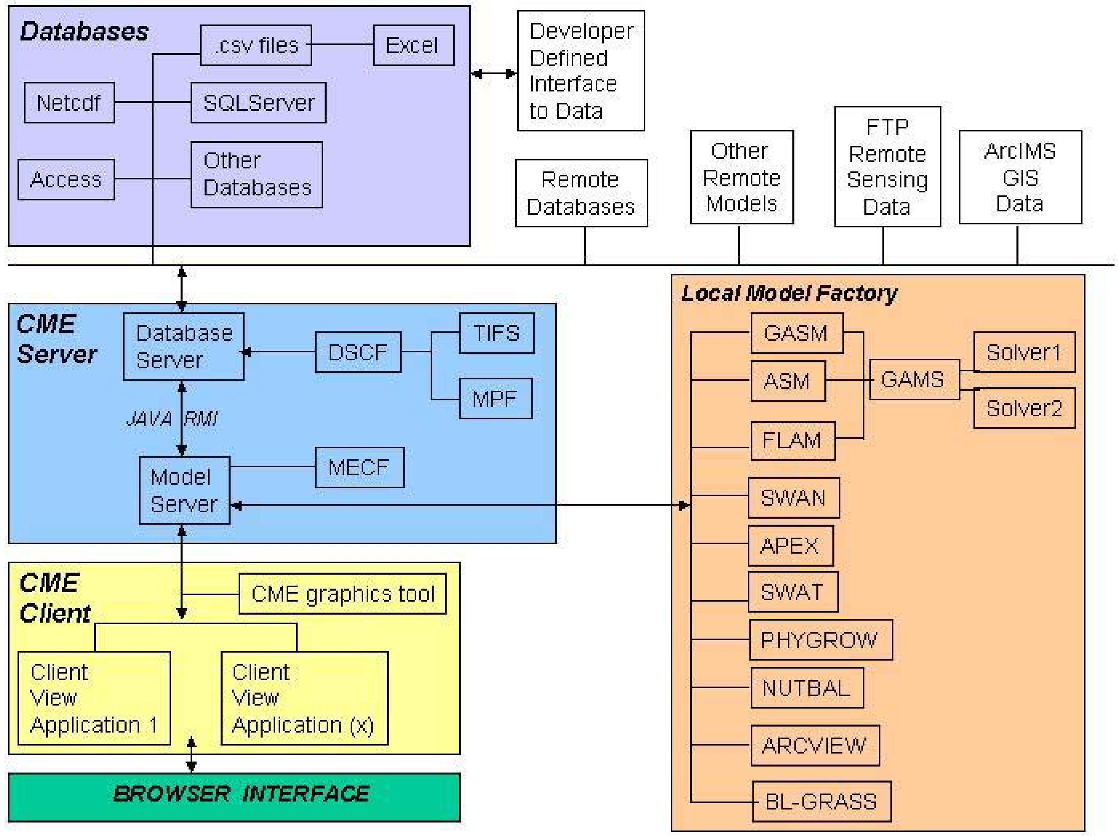

Figure 1. Integrated structure of the Common Modeling Environment (CME).

CME Client

The model client program is a java application, which can also be run on many existing machines and provide rapid local response for interface interactions, as well as access to common data, and access to the remote server for the most up to date version of the simulation model on the most up to date hardware the model maintainers can make available

Graphics Module: This module is comprised of the CME graphics applications and middleware language that defines how the data is presented. We have added the ability to save graphs (including underlying data) from a model run into XML so that they can be emailed to other users of the CME for their viewing and continued analysis. Previously, the only way CME users could share graphs was by converting the graph into a JPG image with screen capture software or by saving it as a postscript file. Previously users could also export the raw data for import into a tool like Microsoft Excel, but none of these options allow a CME user to import that graph back into CME and manipulate it. As part of this feature, the menus were altered to provide a more user-friendly layout and to allow for Graph Save/Import features. Also, the software was altered so that if a user has graphs up when they close down the application, those graphs are automatically restored when the application is restarted.

The CME was designed to allow users to run a suite of models located on a server or multiple servers. This is accomplished by using the Java programming language. Java Database Connectivity (JDBC) is used to connect the client to the database, and Remote

Method Invocation (RMI) is used to connect the client to the servers. The CME is platform independent and creates a client-server environment for model runs; thereby freeing up CPU time and memory on the user's machine that was previously used by the model, and moving data exploration tasks to the client computer.

Client View Module: The Client Viewer defines how the model is viewed by the user. Model developers define those variables that are displayed on the screen and the range of values that can be entered in to the selected model. These inputs can vary from a few variables to a complete data entry system. The most common interface is likely to be models that have already been parameterized, tested and run with prior analyses. Users would then just change a few variables of interest, run the model and observe the output.

CME Server

Model Server : The server application reads its configuration from a user defined "Model Execution Configuration File" or MECF. This file is created by the modeler and tells the CME server application exactly how to access model-specific input data, what variables will be configurable on-the-fly, and what output to generate. A model server parser and model input/output SQL parser have been developed to allow model developers to keep their model designs intact and linked to import/export specification tables. This allows data entry, data output graphing and data exchange over the web. The CME software is all written in Java, which allows the client and server applications to be run on separate machines and communicate via Java Remote Method Invocation (RMI). After the model server program has been downloaded and configured properly to run on a machine, the modeler must create a Model Execution Configuration File (MECF) for the models running on the server. Only one MECF is required per server. This file tells the server process how and where to run a model, where to find the Template Input File Syntax (TIFS) and which output files will be created for users to view. An explanation of the MECF format and TIFS format can be found in the next two sections.

Database Server: The CME server application has the ability to connect to ODBC compliant database via the Java Database Connectivity (JDBC) interface. If the modeler has the input data in a SQL, Access, Oracle, or other database, they can create a CME Database Server Configuration File (DSCF) that tells the CME application exactly where that database resides and how to connect to it. The modeler also must create a Template Input File Syntax (TIFS) file that tells the database server exactly what kind of tables and fields are in the database so that it can form proper queries into the database.

Model Factory

Existing models are encapsulated in a model server process. This model server is configured to know about the required input files, export the results of interest and how to run the model. This allows the incorporation of existing stand alone models, as well as quickly assimilating new models into the suite of tools without undue stress on research model developers. The model server process can be run on any platform that has a java virtual machine. This means existing models on Sun, NT, Windows 95, and Dec Alpha machines can be incorporated into the modeling environment. Model server processes can be distributed across more than one machine to scale up model server performance with demand.

If a modeler would like to add a model to the CME, they would first need to set up a server that is accessible from the web. The server should have the Java Development Kit (JDK) or the Java Runtime Environment (JRE) installed in order to run the model server processes required. The model server process is distributed as a JAR (Java Archive) file, named modelserve.jar. It is available for download from http://cnrit.tamu.edu/CME/downloads. After installing the JDK or Java Runtime on the server machine, the CLASSPATH environment variable should be set to point to the full path where the modelserve.jar file resides, ie: \home\model\modelserve.jar

The current release of the Common Modeling Environment has been improved in terms of consistent server status and restarts with no loss of completed model results. An example of this server and client have been bundled together to produce a standalone PC version of the Phygrow simulation model used in the impact assessment process on rangelands.

To use the CME to run a model, a user must first download a Java Development Kit (JDK) or Java Runtime Environment (JRE) (there is one available from the java.sun.com website.) The CME is a java application and requires a java runtime environment. After a user has installed the JDK or JRE on their machine, the next step is to download the CME client12.jar file from the downloads page. The JAR file is the only file needed for the CME to run on a user's machine. The downloads page contains step by step instructions on how to set up your machine to run the CME. After this completing to procedure outlined, the CME window should appear on the client machine and be ready for model execution. When the CME is run on a client machine, it will appear as a window with a series of action tabs.

RESULTS AND DISCUSSIONS

The documentation and software for the CME can be acquired at http://cnrit.tamu.edu/CME. The site allows viewing of a test that was conducted by interfacing a rangeland model (PHYGROW) and a crop model (EPIC). Currently, the PHYGROW models runs exclusively under the CME environment allowing full parameterization.

The ability to save all the results of a model run into a single compressed file on the CME user's local hard drive was added after observing user activities associated with the beta test of PHYGROW and EPIC. This provides the ability of users to share entire model runs with each other or for a user to be able to take a model run on a laptop while on travel where there may not be an Internet connection. It also allows users of the CME to share model results with each other where one user can make changes and send back to the other. Currently, the CME allows users to save and exchange a link to an existing model running on a particular model server, but this new feature allows for the results of the model run to be backed up, mirrored on other model servers, or accessed when a user does not have an Internet connection to a model server.

To improve speed of the system after observing the test on PHYGROW, the compression sockets were changed for the client and server parts of CME so that they communicate with each other and share data in compressed form. This tripled the speed at which the CME client can interact with models on a server. The performance improvement will be most noticeable for CME users connecting to model servers over slower Internet connections.

After observing use of CME for the past year among an array of graduate students and scientists in our research group, the following enhancements were identified as future development needs:

1. User interface enhancements: Alter the user interface of the CME software so that it is more intuitive and has an improved, user-friendly look-and-feel. An attractive splash-screen describing the software while the software loads while loading with enhanced design of buttons, tabs, menus, etc. so that the program is easier for new users to understand and more intuitively laid-out.

2. Enhanced database interaction: The database interfaces needs to be enhanced to allow CME to more efficiently handle queries and speed up database access time, allowing easier use of other ODBC compliant databases that we currently are not using (like Microsoft Access). These enhancements would allow the results of a model run and place those into the input files for another model run, thereby letting one model's results feed another model's input.

CONCLUSION

The common modeling environment offers multiple model development teams to place their models on the web without altering the code or changing their data structures. The framework provided by the CME system could provide a framework for multiple projects to place the analysis and models used in a wide array of research programs in a computing environment that would provide a cohesive suite of tools for future users. The legacy of the analysis is provided in a form that could be further explored by future users with minimal overhead on the model developers.

The ongoing efforts in collaboration with FAO's WAICENT group offers the most logical entry point for institutionalization of CME. Given the global network of FAO and its strong commitment to distribution of information, CME could play a crucial role in transitioning data into analysis.

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Acronyms Used:

.csv	Comma separated value format extension
ACT	Almanac Characterization Tool
APEX	Agricultural Policy Environment Extender

ArcIMS	Arc Internet Mapping Systems
ARCVIEW	Arc Geographical Information Systems
ASM	Agricultural Sector Model
BL-GRASS	Blackland Geographic Resources Analysis Support System
CME	Common Modeling Environment
CRSP	Collaborative Research Support Program
CURVEEXPERT	Curve Fitting Software
DSCF	Database Server Configuration File
EPIC	Environmental Policy Integrated Climate
ERDAS	Earth Resource Data Analysis System
FAO	Food and Agriculture Organization of the United Nations
FLAM	Farm Level Analysis Model
FLIPSIM	Farm Level Policy Analysis System
FTP	File Transfer Protocol
GAMS	General Algebraic Modeling System
GASM	Global Agricultural Sector Model
GIS	Geographical Information Systems
IAG	Impact Assessment Group
JAVA	Sun Microsystems Computer Language
JDBC	Java Database Connectivity
JDK	Java Development Kit
JPG	Joint Photographic Experts Group Format
JRE	Java Runtime Environment
LANDDEMAND	Livestock Demand for Land Calculator
MECF	Model Execution Configuration File
MPF	Model Parameters File
Netcdf	Network Common Data Format
NUTBAL	Nutritional Balance Analyzer
ODBC	Object Database Connectivity
PAIA	Priority Areas for Interdisciplinary Action
PHYGROW	Phytomass Growth Simulator
RMI	Remote Method Invocation
SANREM	Sustainable Agricultural and Natural Resource Management
SPSS	Statistical Programs for Social Sciences
SOLVER	Analytical add ons for the GAMS environment
SQL	Structured Query Language
SWAN	Soil Water Analysis
SWAT	Soil and Water Assessment Toll
TAMU	Texas A&M University
TIFS	Template Input Files
WAICENT	World Agricultural Information Center
WXGEN	Weather Generator for EPIC
XML	Extended Markup Language

Combinaison de l'expérience régionale et de la gestion holistique pour la recherche d'alternatives d'amélioration de la fertilité du sol de la commune de Madiama[1]

Boureima Traore[2], Odiaba Samake[3], Oumarou Badini[4]

RESUME

La gestion holistique fournit un cadre qui permet de faire un diagnostic des causes et d'identifier des traitements pour la dégradation des ressources naturelles. Dans la commune de Madiama, les exercices de gestion holistiques ont identifié le cycle des nutriments comme pilier de l'écosystème exigeant la modification, complétant l'identification de la fertilité du sol comme problème prioritaire pendant le PLLA. L'identification des technologies efficaces et adaptables pour l'amélioration de la fertilité des sols pauvres de Madiama ou le cumule annuel des précipitations se trouve entre 300 à 700 millimètres. Le caractère aléatoire et irrégulier des précipitations et l'assèchement précoce des eaux de surface constituent de véritables contraintes. Dans ces conditions, un certain nombre de testes de la gestion holistique qui ont suivi les recommandations traditionnelles de recherches a échoué. Cet article présente quelques résultats anticipes de la recherche récente sur la fertilité du sol conduite avec des paysans de la commune de Madiama pendant ces deux dernières années. Les alternatives de la gestion holistiques examinées incluent: (1) l'application au poquet de micro-doses d'engrais minéral pour augmenter le rendements avec des coûts minimaux; (2) l'intégration de la production végétale et animale pour échanger du fourrage de champ contre la fumure organique entre agriculteurs et éleveurs; (3) l'application du phosphate naturel localement disponible (PNT) comme supplément peu coûteux de fertilité du sol; (4) la rotations et l'association de niébe et du mil pour augmenter la fixation de l'azote, la diversité diététique et la production accrue de fourrage.

Mots-clés : dégradation, sol, fertilité, ressources naturelles, gestion holistiques, agriculteurs, éleveurs, fumure organique, fumure minérale, intégration, production végétale et animale

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ABSTRACT

Holistic Management provides a framework for diagnosing causes and prescribing general cures for natural resource degradation. In Madiama, holistic management exercises have identified the Nutrient cycle as a pillar of the ecosystem modification, complementing the identification of soil fertility as a priority problem during the PLLA. Identifying effective soil fertility improving technologies adaptable to poor soil conditions where annual rainfall fluctuates between 300 to 600 mm, rainfall events are irregular, and water tables have been declining is a difficult task. Under these conditions traditional research recommendations fail a number of holistic management tests. This paper highlights recent soil fertility research conducted with farmers in Madiama during the past two years. Holistic management alternatives being tested include: (1) seed hole application of micro-doses of mineral fertilizer to increase yields with minimal cost; (2) the integration of the crop and livestock production to exchange field fodder for manure between farmers and herders; (3) The application of locally available cowpea/millet rotations and intercropping to increase nitrogen fixation, dietary diversity and increased fodder production.

Key words: degradation, soil, fertility, natural resources, Holistic management, farmers, herders mineral fertilizer, integration, crop and livestock

INTRODUCTION

Le diagnostic (PLLA) SANREM/IER effectué dans la commune de Madiama en 1999 a permis de faire ressortir que l'instabilité de la production agricole constitue la principale contrainte de la population à l'heure actuelle. Cette situation entraîne une insécurité alimentaire permanente pour les populations. La commune est caractérisée par un climat tropical alternant deux saisons une longue saison sèche et une courte saison pluvieuse. De fortes températures, un ensoleillement qui dure plus de dix heures par jour. Le total pluviométrique annuel est compris entre 300 et 700 mm. Les pluies sont aléatoires et irrégulières d'une saison à l'autre et on y observe : un abaissement du niveau de la nappe phréatique, une diminution des débits des cours d'eau, un assèchement précoce des mares. La baisse du couvert végétal expose les sols aux érosions éolienne et/ou hydrique et entraîne une diminution de la biomasse végétale et partant une baisse du stock de matière organique. La croissance démographique a entraîné la forte réduction de la durée de jachère voire l'arrêt de cette pratique. Les sols sont surexploités, sans restitution minérale ou organique d'où une baisse rapide de leur fertilité.

La dégradation des sols causée par l'érosion entraîne la perte de 10 à 60 % des nutriments des sols. On estime qu' en Afrique subsaharienne l'agriculture prélève jusqu'à 22kg de N, 6kg de P_2O_5 et 18 kg de K_2O par hectare en l'an 2000, avec une perte nette de 49 kg par hectare. Les prélèvements annuels d'élément nutritifs vont atteindre 60 kg./ha (13.2 millions de tonnes d'éléments) la même année (Bationo A., 1998). Aussi même les terres intensivement fertilisées comme dans les zones cotonnières connaissent-elles un bilan négatif de N et K. La dégradation n'est pas encore arrêtée et la durabilité de la production est en jeu.

L'intégration agriculture - élevage est faiblement développée à cause du caractère extensif des systèmes d'exploitation agricole et d'élevage ; le faible niveau d'organisation, l'analphabétisme, et le faible pouvoir d'achat des producteurs dans la commune de Madiama limitent leur capacité à prendre en mains des volets importants de la gestion intégrée de la fertilité des sols tels que l'approvisionnement en intrants et la commercialisation des produits.

L'identification de possibilités et d'alternatives d'amélioration de la fertilisation du sol adaptée aux besoins des cultures dans la commune rurale de Madiama au Mali est devenue une nécessité impérieuse face à la dégradation galopante de l'environnement, si l'on veut espérer continuer à obtenir des rendements aussi bien économiquement rentables qu'écologiquement durables. La gestion de la fertilité doit se faire dans un cadre global, qui implique tous acteurs qui utilisent les ressources du milieu. C'est dans cette optique que SANREM CRSP avec le WAF-008 a fait l'inventaire et la description des possibilités et alternatives d'amélioration du sol a partir d'une revue bibliographique. Ces alternatives d'amélioration du sol sont toutes testées dans la sous région et ont présenté des résultats pouvant répondre aux besoins des communautés de la commune de Madiama. Pour lever ces contraintes un certain nombre de technologies est proposé. Parmi eux on peut citer :

- Pour une augmentation de la production un apport d'engrais phosphatés est nécessaire, mais son application suivant les doses recommandées est difficile, car le coût des engrais commerciaux est souvent hors de portée des petits producteurs. L'application de phosphore au poquet permet dans une certaine mesure de limiter ce problème en minimisant les doses de phosphore à appliquer tout en ayant un gain de rendement acceptable par rapport à l'investissement (A.C. Bulkert et B. Muchling - Version, A. Bationo, 1998).La dose d'application optimale déterminée est de 4 kg P/ha (c'est-à-dire 9,2 kg/ha de P_2O_5), ce qui est équivalent à 6 g d'engrais complexe 15-15-15 par poquet pour une densité de semis de 10.000 poquets/ha. C'est surtout l'engrais complexe 15-15-15 qui contient 15 kg de phosphore (P_2O_5) pour 100 kg d'engrais. Les doses de phosphore sont placées avec les semences dans les poquets du mil. L'augmentation de la paille et des rendements de gains de mil peut atteindre jusqu'à 70 %. Avec une pluviométrie normale et régulière les risques sont négligeables. Par ailleurs, le phosphore appliqué mais non utilisé par les cultures suite à une mauvaise saison reste en grande partie disponible pour la saison suivante. (A.C. Bulkert et B. Muchling - Version, A. Bationo, 1998). Le projet Intrants/ICRISAT (2000-2001)propose de remplacer les 6g de 15-15-15 par 2g de Phosphate d' ammoniaque (DAP) (18-46-0) qui apporte à l'hectare la formule 3,6-9,2-0 a cause de : la concentration, du prix , de la souplesse d'application de la possibilité d'utilisation selon le besoin et de la limitation des pertes.

- Le Phosphate Naturel du Tilemsi (PNT) distribué dans le Sud du Mali par la compagnie cotonnière nationale, la CMDT, se montre réellement efficace sur les champs, surtout lorsque les pluies sont bonnes. Avec une dose recommandée de 300kg/ha Il présente également un bon effet résiduel. La technique de mélanger le PNT à la terre humide ou à la fumure organique, semble la mieux indiquée pour l'instant (Koné. Y., et al. 2000). l'utilisation du phosphate naturel de Tilemsi (PNT) comme fumure de fond dans le système de fertilisation des cultures à Kadiolo (D.R.S.P.R.,1990/1991) et de la protection des sols contre l'acidification et l'appauvrissement en phosphore a permis d'enregistrer pour ce qui concerne le mil dans la fertilisation de l'association sorgho/mil une différence hautement significative entre la pratique paysanne et la moyenne des traitements phosphatés. La fertilisation de façon générale a abouti à un accroissement de 49% par rapport à la pratique paysanne sans fertilisation.

- L'utilisation de la fumure organique (fumier, poudrette de parc, compost) est une pratique traditionnelle dans les pays du Sahel. Avec la disparition des friches, son rôle dans la restitution des aptitudes productives devient de plus en plus important (Landais et al, 1990). Le fumier est un mélange de déjections animales et de résidus végétaux (litière). Sa production nécessite que les animaux soient affouragés toujours au même endroit et sous abri pour éviter le lessivage des éléments fertilisants. Le transport des fourrages et des résidus végétaux pour la litière, l'abreuvement des animaux, la fabrication du fumier (compostage éventuel), son transport sur les parcelles et son enfouissement posent de nombreux problèmes. Tous ces travaux nécessitent des outils et beaucoup de travail.

De plus, pour que les effets sur les rendements des cultures soient importants, les doses doivent être élevées (5 à 10 t/ha). Or, le nombre des animaux par exploitation est très faible (1 à 2 bovin et quelques caprins). Les fourrages sont constitués essentiellement des résidus de cultures (Dugué P.,1989) Mais avec l'application de cette dose, de grandes quantités d'éléments nutritifs étaient lessivés jusqu'à deux mètres de profondeurs. Par conséquent, 1 à 2 tha-1 de fumier de bétail appliqué chaque année peut être plus efficaces que 5 tha-1 chaque deux ou trois ans.

Les agro-éleveurs pourraient s'investir davantage dans une meilleure gestion de cette ressource, essentielle pour la durabilité de l'agriculture mais consommatrice en travail en pratiquant les parcs améliorés. La technique des parcs améliorés consiste à apporter dans les parcs de nuit des animaux un maximum de matière végétales d'origine et de qualité variable : pailles, résidus de récolte, déchet de battage etc. Les fourrages grossiers distribués au par participent , par la forte proportion des refus, à cet apport de matière végétale destiné à la fabrication du fumier . Des résidus grossiers , même fortement lignifiés, peuvent entrer dans la fabrication ; le piétinement des animaux et les fermentations qui se produisent dans la litière suffiraient à faire évoluer ces matériaux. Cette technique peut être utiliser à Madiama pour deux raisons principales : les troupeaux bovin ovin et caprin (tableau :1) sont de plus en plus souvent gérés à l'échelon familial, ou quartier ce qui facilite ce type d'amélioration et l'équipement en traction animale et en particulier en charrette prend de l'ampleur et constitue une condition indispensable à la réussite de cette technique dans laquelle les transports de matière sont importants. L'intérêt économique d'une telle pratique est l'association partielle probable du fumier aux engrais minéraux en vue d'améliorer leur efficacité, une réduction des coûts des inputs et la diversification des activités productives

- La technique d'utilisation de la fumure organique par parcage au champs est un moyen privilégié que l'on peut utiliser pendant la saison sèche pour la fertilisation des champs de céréales. L'intérêt de cette technique tient au fait que les transferts sont assurés par les animaux ; il y a assurément très peu d'investissement et l'ensemble des déjections (fèces et urines) est bien déposé sur les parcelles durant les temps de séjour concernés qui sont couramment de 14 h sur 24 h, les fèces peuvent être estimés dans ces conditions (Sonko , 1986) par une formule qui intègre le poids des animaux , le temps de séjour par 24 h et le nombre de nuitées . Les quantités déposées sont de l'ordre 50 kg de MS de fèces par UBT et par mois soit l'ordre de 600 kg de MS de fèces par UBT[1] et par an. Ce système a longtemps permis de valoriser les déjections animales des troupeaux transhumants par le biais des « contrats de fumure » traditionnel passés entre les agriculteurs sédentaires et les pasteurs venus pour la saison sèche . Ce type de contrat se fait aujourd'hui rare dans la commune de Madiama ,qui a l'avantage de recevoir de nombreux troupeaux transhumants (Tableau 2 et 3) venus d'ailleurs pour les bourgoutières du Delta Intérieur du Niger et dans les casiers rizicoles. Cet avantage peut être mis à profit par des sensibilisations, des concertations entre éleveurs et paysans afin de lever cette contrainte.

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*L'UBT** : L'Unité Bétail Tropical d'un poids standard de 250 kg vif qui ingère 2300 kg de MS/an soit 6,25 kg/jour excrète environ 1000 kg de MS/an (la quantité moyenne de 600 kg de MS déposée tient compte du temps de séjour sur la parcelle).*

Selon des essais réalisés au Niger par le Centre International pour l'Elevage en l'Afrique (CIPEA, 1995, 1996) le fumier et les urines déposés par le bétail parqué dans un enclos sur le site pendant une nuit, semble être adéquate pour l'obtention de bons rendements (800 kgha-1, deux à quatre fois le rendement des terrains d'expérimentation). Il a été déduit qu'appliquer du fumier une nuit une fois par an, (environ 2,8 tha-1 de fumier et d'urine de bétail, ou bien 3 tha-1 de fumier et d'urine de mouton), convient probablement à certains, mais c'est peut être une trop grosse quantité pour d'autres terrains (Brouwer et al., 1995)). 2,8 tha-1an-1 de fumier et d'urine, déposés par des moutons parqués sur le site pendant une nuit a donné une excellente production de mil (800 kgha-1). Ceci est peut être dû à l'urine de mouton qui fait nettement augmenter le pH de la terre, et par conséquent, même sur les surfaces lessivées, le faible pH du sol ne limite pas pour autant la croissance du mil. L'urine de bovin ne produit pas le même effet. Le fumier de mouton se décompose et est lessivé plus lentement que le fumier de bovin (Brouwer et al., 1995). A Madiama il existe la possibilité que cette technique utilise les transhumants pour le parcage pendant leur attente pour la traversée pour les bourgoutières. Ce parcage peut être géré d'une manière holistique. Il s'agit d'initier des formes de contrat entre paysans et éleveurs afin que les attentes se fassent chaque année dans les parcelles d'un village qui d'une manière concertée crée les conditions d'accueil pour toute la durée de la période.

- A cause du pouvoir d'achat réduit des paysans, l'utilisation des engrais azotée est négligeable dans cette zone. Une façon de pallier à ces deux problèmes est de profiter de la fixation biologique de l'azote par les légumineuses cultivées dans la zone soudano-sahélienne telles que le niébé et l'arachide. Les essais en station ont montré les avantages qu'il y a à adopter la rotation annuelle de culture pure de céréales et de cultures pures de niébé ou arachide (A. Bationo, et al., 1998). Selon Klaij et Ntare, 1995 : Bationo et Vlek, 1997) avec les rotations céréales - légumineuses les rendements des céréales peuvent quasiment être doublés dans le système de culture en rotation par rapport à la monoculture continue de mil. L'évaluation en milieu paysan dans différentes zones agro-écologiques du Niger a permis de conclure que suite à la rotation mil-niébé on obtient des rendements similaires qu'avec l'utilisation de l'azote (30 kgN/ha) en culture continue de mil les autres bénéfices importants liés à la rotation sont : la diminution des parasites, l'amélioration de l'activité biologique des sols, et l'amélioration des propriétés physiques des sols. Cette technique est applicable en zone soudano-sahélienne avec une pluviométrie annuelle supérieure à 350 mm pour la rotation avec l'arachide. Cette technique présente des limites d'application telles que les investissements importants en semence, en traitement chimique.

- Les association légumineuses sont les cultures effectuées sur le même terrain, en même temps, mais les semis et les récoltes sont faits séparément. Les cultures peuvent être faites ligne par ligne ou intercalaires. Dans le sol, à l'interface sol-racine, la plante peut favoriser la dissolution des phosphates en modifiant les conditions du milieu (acidification, activité microbienne) et donc la biodisponibilité des éléments nutritifs (Haynes RJ, 1988). C'est ainsi que la baisse du pH permet la dissolution des phosphates naturels et augmente l'assimilation du phosphore (Khasawneh FE., 1978). Les légumineuses par la fixation de l'azote atmosphérique, contribuent à diminuer le pH de la rhizosphère ; elles pourraient ainsi augmenter la biodisponibilité du phosphore. Dans un système d'association légumineuse - céréale, pratique courante en Afrique de l'Ouest, la dissolution des phosphates naturel par la légumineuse pourrait donc avoir un effet bénéfique pour la céréale.

METHODOLOGIE D'UDE

Les premières activités ont consistés a analyser la problématique de ea gestion durable des ressources naturelles et des conflits dans la commune de Madiama en équipe pluridisciplinaire et inter-institutionnelle (SANREM, IER, WSU, CARE-Djenne et autres partenaires) cela a conduit a un diagnostic participatif a partir d'un PLLA dans la commune de Madiama. Le PLLA a permis de clarifier le contexte de développement et d'identifier les différents acteurs qui interviennent dans la gestion des ressources naturelles de la commune.

Cette identification des acteurs a permis de mettre en place un Comite Communal de Gestion de Ressources Naturelles (CCGRN) qui est l'émanation des différents Comites Villageois de Gestion des Ressources Naturelles (CVGRN) préalablement mis en place dans chacun des dix villages de la commune

Le CCGRN et les différents partenaires ont reçu plusieurs formations sur la gestion holistique des ressources naturelles et des conflits. Ces différentes formations ont permis au CCGRN d'une manière concertée avec tous acteurs impliqués dans la gestion des ressources et les différents partenaires au développement (SANREM, IER, WSU, CARE-Djenne, Administration et autres partenaires) de procéder a une analyse des différents systèmes et de leurs contraintes dans un contexte de gestion holistique afin d'identifier des options de recherche et développement. Ces options ont été évaluées et hiérarchisées. Des plans d'action ont été élaborés, les échéances et les acteurs impliqués ont été également déterminées d'une manière participative.

Ainsi le thème sur la combinaison de l'expérience régionale et de la gestion holistique pour rechercher des alternatives d'amélioration de la fertilité du sol de la commune de Madiama a été retenu pour contribuer a lever une des contraintes principales qui est l'insécurité alimentaire dont l'analyse causale a montré que le cycle des nutriments des écosystèmes pose problème et que la faible fertilité du sol est un maillon faible du système. Pour gérer cet aspect nous avons mis a contribution tous les acteurs qui exploitent cette ressource afin de prendre en compte les opinions de tous et les possibilités que le milieu peut offrir pour lever la contrainte.

Les différentes rencontres entre chercheurs et CCGRN et les paysans autour des technologies proposées ont permis d'expliquer ces technologies. En assemblée générale des paysans se sont portés volontaires pour conduire les différents tests. Les différents travaux ont été exécutés par les paysans au champ sous la direction du chercheur et des observateurs chargés du suivi.

Trois séries de tests ont été conduites dans les10 villages de la commune de Madiama : il s'agit du Test de la rotation Niébé – mil, Test de l'association Niébé / mil, Test de la fumure organique (poudrette de parc et parcage au champ), Test de la fumure minérale (PNT et fertilisation localisée par poquet) sur la variété locale de mil et de sorgho.

Les terrains choisis sont de type sableux , sablo-limoneux, argileux suivant le type de culture (mil, sorgho) relativement plats, et homogènes nous avons tenu compte des gros arbres pouvant influer sur la végétation des plants. La préparation du sol est faite à la charrue dans toutes les parcelles de test et a consister à faire le labour à billons. Les parcelles élémentaires ont une superficie de 150m^2 (15m x 10m). Les intrants utilisés pour les différents traitements sont : Le complexe 15 15 15, le PNT, la fumure organique de bovin et de petits ruminants, le Niebe, le mil et le sorgho (les varietes du paysan).

Les dispositifs expérimentaux sont les mêmes pour tous les tests, ce sont des parcelles d'observations à quatre répétitions et les traitements varient suivant le test. Les parcelles sont matérialisées par des repères. La densité de semis du mil et du sorgho est de 0,80 m entre les lignes et 0,75 m entre les poquets. Le mil et le sorgho sont semés à plusieurs graines par poquets (minimum 8 graines) en ligne. Toutes les cultures ont été démariées à deux plants par poquets dix à quinze jours après le semis au premier sarclage et en condition d'humidité suffisante du sol . Tandis que pour les tests de rotation, avec le Niebe en tête de rotation et l'association la densité de semis du niébé : 0,85 m entre les lignes et 0,75 m entre les poquets. Le semis est de deux à trois graines par poquet et en ligne Les lignes de mil alternent avec les lignes de niébé. trois traitements phytosanitaires du Niebe ont été faits : le premier à 50% floraison, le second dix à quinze jours après le premier et le troisième dix à quinze jours après le deuxième au Décis à 1 litre à l'ha. Deux sarclages à la charrue ont été faits : le premier sarclage 10 à 15 jours après la levée, le 2eme sarclage à 20 jours après le premier. Toutes les opérations pour chaque test ont été effectuées le même jour pour tous les traitements.

Le suivi de l'état végétatif des plants pendant leur cycle (germination, tallage, démariage,, date de 50 et 100% floraison, épiaison et maturation) a permis d'estimer la densité du mil et celle du sorgho après démariage, et à la récolte par comptage des plants par poquet de la parcelle élémentaire. Les rendements grains, biomasse (épi, feuille, tige, racines), ont été évalués. La quantité de main d'œuvre utilisée et les temps des travaux ont été estimés. Pour évaluer l'effet des précédents sur la fertilité, des échantillons de sols ont été prélevés au niveau des horizons 0 – 20, 20 – 40, 40 – 60 avant le semis et après la récolte pour déterminer leur teneur en matière organique, et en éléments minéraux tels que le N,P,K , la texture, les bases échangeables. Les plantes sont analysées pour déterminer leur taux en N, P, K. Les résultats des analyses ne figureront pas dans ce rapport

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ANNEXE 1

Tableau 1 : Effectif par village de cheptels bovins Ovins et caprins de la commune de Madiama et le nombre moyen d'animaux par ménage.

Villages	Nombre de ménages	Effectif de bovins		Effectifs des Ovins et Caprins	
		Effectifs déclarés bovins	Effectifs moyen de bovins par ménage	Caprin	Ovin
Torokoro	74	100	1,35	300	150
Nérékoro	54	1700	31,48		
Bangassi	194	630	3,25	250	200
Promani	150	520	3,47	100	50
Nouna	35	500	14,29	-	-
Téguégné Dougourani	58	165	2,84	160	100
Siragourou	82	410	1,83	-	-
Tombonkan	76	200	2,63	-	-
Toumadiama	150	100	0,67	100	200
Madiama	365	750	2,05	-	-

Tableau 2 : Présence des troupeaux bovins transhumants dans la commune de Madiama

Villages	Nbre de troupeaux/j le jour "J" de la traversée	Taille/ troupeau	Temps de Séjour	
			Avant la date de la traversée (j)	Après la Traversée Retour pour exploiter les résidus de récolte (mois)
Torokoro	5	100	1 - 7	(3) Déc-Fév
Nérékoro	500	100 - 150	30 - 60	-
Bangassi	20	50 - 200	7 - 15	(6) Janv-Juin
Promani	400	50 - 300	10 - 15	(2) Mai-Juin
Nouna	100 - 200	50 - 200	2 - 7	(7) Déc-Juin
Téguégné	15	40 - 60	30	-
Siragourou	25	400	60	(3) Fév-Avr
Tombonkan	30	30 - 200	15 - 20	-
Toumadiama	1 - 5	20 - 100	30	-
Madiama	1000	50 - 100	30	-

<u>Tableau 3</u> : Présence des petits ruminants transhumants dans la commune

Village	Arrivée	Effectifs déclarés				Séjour avant la traversée (j)
		Nbre de Troupeaux		Taille/Troupeau		
		Caprins	Ovins	Caprins	Ovins	
Torokoro	Septembre	20	-	50-100	-	-
Nérékoro	Octobre	40	30	60-150	100-300	40
Bangassi	Sept/ Oct.	30	20	15-80	50-200	15
Promani	Septembre	6	8	100-150	20-100	-
Nouna	Mi-Octobre	2-5	5-10	30-100	100-300	15
Téguégné Dougourani	Sept/ Oct.	10	3	60-100	60	1-30
Siragourou	Octobre	3-10	-	40-200	-	-
Tombonkan	Septembre	40	20	800	800	-
Madiama	Septembre	1-10	-	50-100	-	-

Promoting More Sustainable Land Use in the Semi-Arid Tropics Through Improved Market Infrastructure: A Malian Case Study[1]

Jeffrey D. Vitale[2] and Richard Woodward[3]

ABSTRACT

This paper is concerned with the extent to which semi-arid regions should remain involved in food production. Current low-input farming practices in these drier areas have pushed cultivation onto the marginal lands, threatening the sustainability of their already fragile ecosystems. With higher productive zones available, such as the Sikasso region of Mali, increased food flows into the semi-arid areas could be used to relieve land pressure. Central to this question is the priority that farmers place on satisfying subsistence food needs with on-farm production, a strategy that avoids risk from high market prices should drought conditions ensue. To determine the feasibility of increased food flows, a farm model was developed that detailed the additional risk farmers would need to incur if they increased their reliance on food markets. The model included an environmental subcomponent (EPIC) to estimate the degradation costs from continued expansion onto marginal areas. Policies to improve market infrastructure resulted in a significant decrease in the use of marginal lands. The modeling activities suggest a reduced, but more sustainable, role for food production for the semi-arid areas.

INTRODUCTION

Soil degradation has emerged as a primary concern for policy makers since it can significantly reduce the soils capacity to produce food and sustain rural livelihoods (Lal 2001). Although the effects of soil degradation are subtle in the short run, and often appear to be overcome by technology or land expansion, noticeable declines in farm productivity, agricultural GDP, and global food losses have been reported due to soil degradation. Over the past half-century, soil degradation has been estimated to account for about a 9 percent decline in yields, agricultural GDP losses from soil degradation have reached as high as 10 percent, and global food production losses due to soil degradation have been estimated to be about 9 percent of total world food production (Bishop and Allen, 1989;Stocking and Pain, 1983;Lal 2001). If soil degradation is not adequately addressed, it is likely to jeopardize future food security for many countries in the developing world (Scherr and Yadav, 2001).

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The effects of soil degradation are of particular concern for Sub-Saharan Africa (SSA), as many areas have been identified as environmental "hot spots" for declining soil nutrients, soil erosion, and vegetative degradation (Scherr and Yadav, 2001). SSA countries are susceptible to soil degradation due to their hot and dry agro-climatic conditions that prolong the natural means of soil restoration compared to more temperate regions. This explains, in part, why the region's food production losses from soil degradation are about 6 percent higher in SSA than the global average (Lal 2001). The impact of potential losses in agricultural GDP is more severe in these countries since their economies are highly dependent on agriculture, and they have limited ability to enhance food security through imports.

In the Sahel of West Africa, population pressure is expected to aggravate the problems associated with soil degradation, and to place additional strain on already fragile agro-ecological systems. The resulting increased food demand means farmers will have to sharply increase food production if there is any hope of reaching long-term food security benchmarks, such as year 2020 scenarios (Sanders at al., 1996). So far, the response of farmers to population pressure has for the most part been to increase production through area expansion onto marginal lands. In northern Burkina Faso, for example, the change in land use for a typical village between 1945 and 1995 showed an annual increase in land use roughly proportional to annual population growth (2.5 percent), with a dramatic increase in land clearing beginning in the mid 1980's (Reenberg et al. 1998). In Mali, satellite imagery on cropland use intensity (CUI) reveals a significant number of areas in a high land-use intensity state, where active cropland constitutes over 90 percent of available land (FEWS 1997).

While the move onto marginal lands may be an optimal strategy for farmers in the short run, the environmental consequences of this practice may grow large over time:marginal lands serve an important role in these eco-systems as natural barriers to wind and water erosion through their vegetative covering (Vierich and Stoop, 1990). Higher quality lands lower on the topo-sequence are subjected to higher erosion rates and yields from soil degradation are expected to fall faster as more marginal land is brought into production.

When viewed from a broader societal perspective, therefore, choices made by farmers might result in large social costs and reduced food security. However, with proactive policy engagement, the corresponding social costs from increased land pressure can be reduced. This would amount to enacting mitigation policies that would provide incentives to farmers to adopt more environmentally savvy land management practices.

Important socio-economic factors have been identified that explain why farmers often employ poor land management practices that, over time, accelerate environmental degradation. These factors include the connections between poverty and soil degradation (Reardon and Vosti, 1995), the effect of poor agricultural polices on soil degradation (Heath and Binswanger, 1996; Lopez 1997), and the lack of private ownership in the traditional land

tenure system (Larson and Bromley, 1990). The link between poverty and degradation[1] are primarily rooted in liquidity constraints that make agricultural investments difficult and pressing concerns to satisfy food subsistence needs and income targets that manifest into high discounting rates. In many countries, poor economic and agricultural policies have in way or another discriminated against domestic farmers, and often the result has been depressed market prices and inadequate access to new technology. Hence, directing farmers toward improved land management requires an understanding of both the economic realities faced by farmers and the underlying bio-physical processes to soil degradation.

Although the literature associated with population and land pressure has long been associated with "dismal economics", and more recently with "downward spirals"and "tragedy of the commons", there are policy options are available to mitigate resource degradation. Intensification and technological change have the potential to end cycles of poverty and to pull farmers out of the "downward spiral". Even in the drier sorghum and millet areas, new technologies have been developed that have shown significant yield increases (Matlon 1990). Although their use has been limited, it is likely that institutional factors and poor policies[2] explain the low adoption. With a reversal in pricing policies in favor of farmers the impacts of these technologies on food production and incomes could be large (Coulibaly et al. 1998).

A second policy alternative to mitigate soil degradation is to improve market infrastructure and increase cereal flows from the higher potential zones in the semi-humid areas to the drier semi-arid areas (Barbier 1998). The semi-humid areas of the Sahel have been one of the more successful regions for new technology introduction. Coupled with a longer and more reliable rainfall season, these regions have a strong potential to supply the areas prone to inadequate rainfall (Sanders et al., 1996). It is believed that farmers associate a fairly high cost with market participation, and that this motivates them to produce nearly all of their food on their farm. If cereal markets were improved, then farmers in the drier areas are likely to increase market participation, and substitute the food produced on the marginal lands[3] with cereals purchased in the market.

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[1] This paper will show that under existing socio-economic conditions, farmers have a strong incentive to clear new lands as opposed to intensifying production. The advantages of extensification in the short run are clear to the farmer: new lands bring forth an additional supply of soil nutrients at a lower cost than purchasing fertilizers to replenish soil nutrient stocks on already cultivated lands.

[2] Three specific factors that have hindered efforts to intensify are the generally poor marketing infrastructure, the low profitability of mineral fertilizer applications, and weak off-farm income opportunities. The poor marketing posture results in depressed revenues in times of surplus, and high food prices when on-farm production falls below subsistence. The high food prices combined with low incomes places a particular burden on the household, which manifests in a strong preference towards producing subsistence food needs. This response to risk results in a crop portfolio that is geared towards food production in the below normal rainfall years, and in cases where farmers overcompensate the pressure on land is significantly increased. The weak off-farm income opportunities eliminates an alternative manner of generating liquidity for purchasing agricultural inputs.

[3] Production on the higher quality lands near the bottom of the topo-sequence would be maintained.

To investigate how farmers land use is likely to change over time as farmers respond to population pressure, this paper begins with a conceptual model of farmer's decision making. The model includes soil degradation, and focuses on how the choice between continued land clearing and intensification is determined by the farmer. An empirical model is then constructed, and is used to test two factors thought to explain excessive land clearing: high future discount rates and lack of liquidity. The model is then used to test the effectiveness of policies to mitigate poor land management practices through improved food markets.

The focus of this paper is on the Sudanian region of southern Mali, the country's primary cereal producing region. The primary constraint to production is low soil moisture availability, as a large portion of the regions' precipitation is lost to evapotranspiration and water runoff. This region is an appropriate case study for environmental degradation since population pressure and the lack of quality lands has significantly reduced fallow periods. Expansion onto marginal lands has already taken place in many areas, and the subsequent degradation and inherent low productivity of the marginal lands is likely to pose a threat to feeding a fast growing population over the coming few decades. The conditions found here also confront farmers in other countries of the West African Sahel

CONCEPTUAL FRAMEWORK

The use of bio-economic modeling in studying environmental effects and land use change in smallholder farming effects has been established in a general framework (Beaumont and Walker, 1996), and applied to case studies in Mexico (Barbier 2000, 1); Mali (Ruben and van Ruijven, 1998); Ghana (Lopez 1997); Philippines (Shively 2001); and Senegal (Sankhayan and Ofsted, 2001). While the approach in this paper is similar to all of those, it most closely resembles Beaumont and Walker, and Lopez in that the focus is on how individual farmers make decisions, and the extent to which degradation costs are internalized.

This section establishes the links that are likely to exist between farmer's decision making and natural resource management. The focus is limited to the choice between land clearing and intensification, and how this is likely to be made from the present through the 2030 benchmark.

Private Costs

Although smallholder farmers throughout SSA have been found to make decisions according to multiple-objectives (Barnet et al., 1982), the most important objective to farmers is generally satisfying food subsistence needs. This is an extension of the safety-first method of risk analysis (Roy 1952), since household subsistence needs are satisfied before profit motives are considered. Although the priority farmers give to natural resource management objectives is less well understood, farmers that choose to satisfy food subsistence objectives over a long planning horizon implicitly assign a strong weight to resource management.

This simplified version of farmer's decision making, limited to food subsistence and profit maximizing objectives, is formalized in the following equations.

$$\text{Max.} \qquad e^{-\beta t}\int_0^T \int_0^F (P_t Y_{\phi At} - C_{\phi At})dA \tag{1}$$

$$\text{S.T.} \qquad \int_0^F Y_{\phi At}dA + B_t \geq e^{-rt} HH \tag{2}$$

$$\frac{dY_{\phi At}}{dt} = \alpha(F_{t-\tau}, E_{\phi At})Y_{\phi At} \tag{3}$$

Equation 1 states that the farmer's objective is to maximize the present value of profits. The two decision variables in the model are the level of technology, ϕ, and the frontier, F. Production is assumed to be along an idealized slope that represents the change in soil quality that is associated with the topo-sequence's altitude, A. Yields, $Y_{\phi At}$, depend upon the location along the topo-sequence, A, as well as technology, ϕ. Profit is given as the sum of revenue (yield times price, P_t) less production costs ($C_{\phi At}$). Total profit is obtained by integrating along the slope from 0 to the end of the frontier, F.

Equation 2 is the food subsistence constraint, which requires that the farmer produce enough food to feed his family for an annual food demand, HH. One consequence of a fast growing population is the increased demand for food production. Since food demand is proportional to household size, its growth rate over time is taken to be r, the household growth rate.

Equation 3 describes how yields, Y, change over the course of time in response to erosion and nutrient depletion. The general form of this equation allows soil erosion caused by marginal land clearing to induce degradation on soils lower on the topo-sequence, since erosion at time t is given by the history of frontier expansion, $F(t-\tau)$. Yields depend on altitude (A) and technology (□). An erosion vector (E) captures changes in soil depth and soil nutrient levels. Productivity is highest at the lowest end of the toposequence (A=0) where the heavier, alluvial soils are located, and along the slope soil quality declines as the altitude, A, is increased (Dalton 1996).

Degradation and Technology Choices

The idealized slope assumption contains all of the erosion costs within the confines[4] of the farmer's own fields. Farmers are likely to internalize at least some of the on-site degradation costs in their private decision making. The two factors included in this model that determine their preferences for internalizing degradation costs are the discount factor (□), and the planning horizon over which farmer's decisions are made (T).

[4] The model presented here cannot capture the effects of externalities arising from the communal land tenure system. However, it is likely that within the extended family organization of the village, the farmer would internalize degradation costs imputed on fellow village members nearly to the same extent as he would his own.

The influence of soil degradation on crop technology choices is apparent from the optimality conditions of the decision-making model:

$$\lambda_{1,t} = \frac{\frac{\partial C_{\phi A t}}{\partial \phi}}{\frac{\partial Y_{\phi A t}}{\partial \phi}} \tag{4}$$

$$\lambda_{1,t} = \frac{C_{\phi A t} + D_t}{Y_{\phi A t}} \tag{5}$$

Equation 4 is the FOC for the intensification parameter, ϕ, which equates the marginal cost of increasing yields (through intensification) to $\lambda_{1,t}$, the marginal cost of satisfying home production at time t. Equation 5 is the FOC associated with extensification, F, which equates the average cost of yields at the frontier plus the present value of increased food costs from degradation (D_t) to $\lambda_{1,t}$, the marginal cost of satisfying home production.

As time progresses, the increase in household size places a larger demand on food subsistence requirements as stated by Equation (2). Here, the key issue is how the farmer responds, and whether he would choose to intensify his production through increasing ϕ, or through expanding the frontier F. The farmer's response to population pressure depends upon three factors: (1) the yield response along the slope to intensification, (2) the cost of increasing yields from intensification relative to the absolute yields from extensification, and (3) the extent to which the farmer internalizes resource degradation costs into his decision making (through longer planning horizons and lower discount rates).

When these factors are considered, there is good reason to suspect that extensification would be the farmer's primary response. Intuitively, Equations 4 and 5 state that intensification is only profitable at locations where the marginal cost of increasing productivity from intensification is lower than the average cost of production at the frontier. This is clearly a challenge to technology, since yields on the frontier are typically about one-third of the yields from intensification, yet the out-of-pocket costs from intensification are often ten to fifteen times as large (Coulibaly 1995; Dalton 1996). Thus, it reasonable to expect that intensification would be limited to small areas lower on the topo-sequence where the response to intensification is greatest, and for production increases to be achieved by continued frontier expansion.

The exception to this would be farmers with a long time horizon. Given the ideal slope, expansion onto marginal lands increases erosion run-off and degrades soil across the topo-sequence, reducing productivity (lower yields) on all of the farmer's fields. If these degradation costs, D_t, are large enough, then the costs of extension would grow large enough to make intensification more attractive and reduce land clearing.

EMPIRICAL MODEL/DATA

The theoretical model presented in the previous section is used as a basis for an empirical model of farmers decision making, which includes additional socio-economic realities confronting farmers. One is the role that market purchases play in satisfying food subsistence. Farmer's often-stated preference for using home production to satisfy subsistence indicates a certain degree of aversion to relying on markets. This preference can be explained by the uncertainty in cereal prices and cash availability. Farmer's are considered to plan for market purchases in a conservative manner, assuring that they can be financed even if cereal prices rose and their income fell. Based upon this, the empirical model includes a cash constraint that limits the amount of food that can be purchased to 15 percent of the households subsistence level.

A second constraint is included to limit the amount of cash available for purchased inputs. Observations indicate that about $150 would be available for purchased inputs (Coulibaly 1995). Households invest in purchased inputs provided that the returns are sufficiently large relative to returns from alternative uses. In addition, land and labor constraints are also included in the empirical model.

The empirical model is discrete in time, space, and technology; this representation allows for numeric solutions using computer software (GAMS). The idealized slope is operationalized by dividing land into four types of varying quality: alluvial, low-slope, mid-slope, and marginal. This maintains consistency with the observed land tenure system that grants to each farmer a handful of plots, with the higher quality plots rationed to maintain some degree of equity. Using field observations, the prototypical farmer is taken to have three plots of the relatively high quality land (3 ha in each plot), with additional plots of marginal land (of size 3 ha) that can be introduced into his cropping system.

The transition of yields over time, as indicated by Equation 3, was obtained[5] using EPIC, a biophysical crop production model. EPIC estimates yields based upon several biotic factors that include: soil layer profile, nutrient availability, soil moisture, temperature, and humidity. EPIC tracks soil erosion and the flow of soil nutrients over time. Erosion estimates were obtained for a thirty-five year period from 2000 to 2035. Baseline yields for the first year of the simulation were calibrated to observed yields in southern Mali (Coulibaly 1995; Dalton 1996). Calibration of the future yield was limited since data on long run erosion is scant.

The prototypical household has a size of 26 persons in the base line, with an annual growth rate of 3 percent. Typically about one-half of the household is available for agricultural labor throughout the growing season (Coulibaly 1995). During peak labor demand periods, planting and harvesting, the remainder of the household is made available. Household labor supply was increased at the same rate as the growth in household population (i.e. no urban migration). Travel time to the marginal fields was accounted for by increasing labor demand.

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[5] The yield estimates in this paper are a first attempt at quantifying the long-run yield effects induced by land clearing. Next generation estimates will use SWAN, an updated version of EPIC that can more systematically handle changes in surface and sub-surface water flow along the topo-sequence.

RESULTS

The empirical model is used to analyze three scenarios that encompass a thirty-five year simulation period (2000 through 2035). In the Baseline scenario, farmer's per-capita income, food prices, and input prices are all held fixed at year 2000 levels. The planning period that is used by the prototypical farmer is varied[6] from one to thirty-five years. The New Technology scenario considers changes in input costs to account for varying degrees of success in developing input distribution channels. In the model, all input costs required for intensification are increased at the start of the simulation, and then held there for the entire simulation period. The Market scenario considers the effect of lower long run food prices from improved market infrastructure. In all three scenarios, per-capita income available for food purchases and per-capita liquidity available for purchasing inputs remain constant[7].

Baseline

In the Baseline scenario, the model results indicate that a much faster conversion rate of marginal land occurs for farmers that plan over short horizons, such as 5, 10, 15, or 20 years (Figure 1). Over the first twenty years of the simulation period, land clearing corresponds to an average increase of about 5 percent for farmers with a planning horizon less than fifteen years. This is about two percent higher than the concurrent growth in population, and would appear to be an acceleration of land clearing compared to the field observations from Burkina Faso that were noted above.

When farmers plan over a longer horizon of at least thirty years, land clearing is significantly reduced, and would not even begin for the first ten years (Figure 1). Throughout the first twenty years, marginal land clearing would be less than one-half of the clearing that would take place for farmers with a shorter planning period, and average increase in land clearing would be less than the growth in population.

With short planning horizons, therefore, extensification is more profitable since fresh stocks of nutrients appear to be "freely" available in the marginal lands, and much cheaper than replenishing nutrient stocks using chemical fertilizers on already cleared lands. Without considering future degradation costs, the effects of degradation only become apparent when it is too late, since degraded lands are much less responsive to intensification and take many years to be restored back to any semblance of their original conditions. Longer planning horizons include more of the future degradation costs that induce intensification early on in the planning horizon before degradation sets in, and at a time when new technology responds best. With more intensive farming in the initial years, less degradation is encountered later in the planning period, and the need to clear additional land is reduced.

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[6] For instance, a five year planning period would be run consecutively seven times.

[7] The discount rate, β, was found to be have little effect on model outcomes since it was the food subsistence constraint that was the driving factor. For completeness, a discount rate of 10 percent was chosen.

New Technology Scenario

When the prototypical farmer has future expectations of increased access to new technology through lower input costs, land clearing practices were found to change only slightly. Reductions in input costs of up to 50 percent from existing levels induced only a minor increase in intensification. The ineffectiveness of lower input prices in mitigating resource exploitation appears to be by the short planning horizon that continues to view land clearing as the most profitable alternative, and fails to incorporate enough of the future degradation into present decision making.

With longer planning horizons such as thirty years, the effect of higher input prices is to greatly shift the farmer's food security strategy from self-sufficiency to one where food markets are used to satisfy subsistence (Figure 2). This shift in food security strategy would begin if input prices increased by at least 50 percent, and increases if input prices were to increase by 100 percent. The switch would occur at around the tenth year of the planning horizon, about one-third of the way to the 2030 benchmark. For farmers with short planning horizons less than thirty years, the higher input prices would have little effect since these types of farmers hardly utilize purchased inputs.

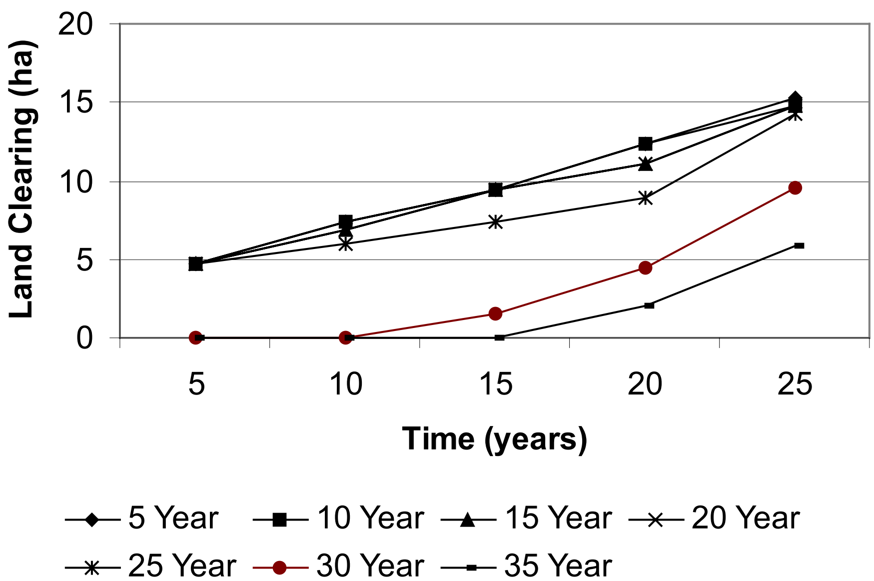

Figure 1 Land Clearing for Several Planning Horizons

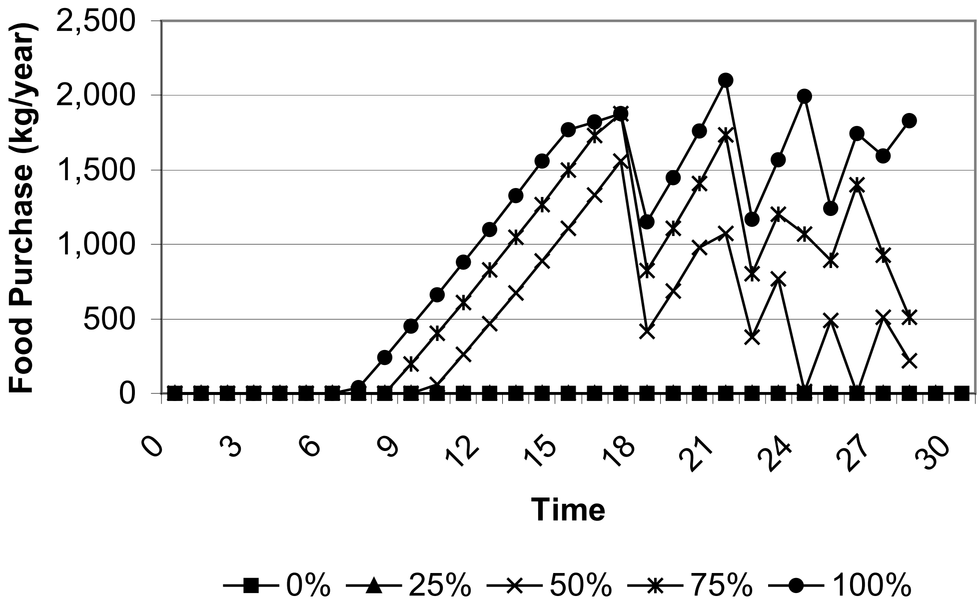

Figure 2 Food Purchases Under Influence of Higher Input Costs (35 Year Planning Horizon)

Market Scenario

When the prototypical farmer has future expectations of lower cereal prices, land clearing is only changed slightly[8]. This is explained since for the first 25 years of the planning period, farmers are self-sufficient, and do not rely on market purchases to satisfy food subsistence. As with the input prices, the effect of the short planning horizon appears to dominate farmer's decision making, and fails to realize the benefits from a strategy that uses food purchases to reduce home production and mitigate degradation from marginal land clearing.

DISCUSSION

The results indicate three different land use patterns that could emerge. The most environmentally sound pattern would be if baseline input prices were maintained and farmers were able to have a sufficiently long planning period of about 30 years. Intensification would occur early on, marginal land clearing would be minimal, and farmers would remain self-sufficient throughout the simulation period. A slightly less environmentally sound land use pattern would result if input prices increased. In this case, farmers would need to purchase food to meet subsistence needs fairly early in the simulation period, although land clearing would only be slightly higher than when input costs do not increase. The third land use pattern is the least environmentally attractive case,

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[8]Model runs not reported in this paper showed less than a 65 percent change in land use among any of the planning horizons.

and corresponds to farmers having a short planning period. This would result in substantial land clearing, food aid requirements by the year 2025, and degraded lands by the year 2030. Moreover, the short planning periods would not respond to policies aimed at mitigating land clearing through lowering input and food prices.

CONCLUSIONS

The two major implications for policy makers is to find innovate ways to extend the scope of farmer's planning to include future degradation costs, as well as to provide efficient input markets to provide farmers with new technology before significant soil degradation is encountered. Extending farmers planning horizon won't be easy, since farmers face immediate economic concerns and are likely to have rather high discount rates. Still, there will be a need to emphasize the importance of the need to switch to intensification early on before significant degradation has taken place, otherwise the productivity gains from intensification will be lost to degradation.

If input markets are not well developed, then policy makers would need to be aware that increased cereal flows into the drier areas from the higher potential zones would be required. The need for cereal flows to flow from the higher potential areas to the drier zones requires additional considerations for the policy makers. One would be whether the supply response from the higher potential zone would maintain low food prices, affordable to consumers, and yet sufficiently high enough to provide incentives to producers. It might be the case that food exports could only be achievable with additional technology introduction in the semi-humid zones, which is likely to require complementary policies to assist development of the input supply channels. Also, consideration would need to be given to whether the higher potential zones would incur significant soil degradation as a result of their exports to the drier areas.

If planning periods are not extended, a second and much less desirable land use pattern would result. This pattern would leave the environment fairly well degraded by the year 2030, even though farmers appear able to meet the 2030 benchmarks. With short planning horizons, increasing population pressure does not coincide with higher levels of intensification that might have been expected. In this case, the falling costs of labor, coupled with the cheap stocks of nutrients contained in the marginal lands, are more profitable than intensification techniques, and the associated degradation costs from land extensification are not visible in the short run planning.

The short planning horizon appears to be the driving factor in farmer's decision making. Policies to lower food prices to reduce pressure to home produce food, or lowering input prices to induce more intensification, would be ineffective in reducing farmer's propensity to clear new land. The short-run profitability of the new lands are made very apparent to farmers with a narrow temporal view, and could only be overcome by very aggressive, and most likely unrealistic, input or food subsidies.

Policy makers should be aware that future expectations of greater cereal availability, such as the food aid, could increase land clearing from moral hazards. Farmers would have reduced incentives to conserve land resources since future food aid would be available after significant resource degradation has already taken place, which is likely to be a cheaper alternative to the farmers than mitigating degradation through proactive intensification. Ironically, the poverty trap is likely to provide some incentives to conserve, since limited future food purchasing power induces farmers to maintain home food production out into the future.

Clearly, one place for policy makers in the West African Sahel to look for optimism is the Machakos district of Eastern Kenya (Barbier 2000, 2). There the combination of market linkages, improved crop production practices, and adequate policy have been sufficient to counteract the effects of environmental degradation, and to maintain significant human carrying capacity. While the extent that this can be translated to different agro-ecological and socio-economic conditions remains to be studied, it points out the potential for appropriate incentives to move farmers to adopt more environmentally friendly production methods.

As for future research, it is suggested that next generation modeling activities include a more general set of land clearing activities, such as over-grazing marginal lands and deforestation associated with firewood. The social costs would also need to be expanded to include the negative impacts from lower village livestock populations and reduced land available for the nomadic pastoralists who rely on communal grazing lands during the dry season. Considerable feedback among the three activities is expected as they compete for a continually shrinking supply of land. Additional analysis could also consider how poor weather would factor into the farmers decision making, and if it would further aggravate land extensification through production risk.

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