Integrating Indigenous Knowledge and Modeling to Evaluate Options for Agropastoral Systems Development

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ABSTRACT

Planning for dryland agropastoral systems development requires the integration of a range of quantitative and qualitative biophysical and socio-economic information. A Geographic Information System (GIS) database and set of spreadsheet models form an effective platform by which to model the production system and their components at a variety of scales. The process involves the capture of indigenous knowledge through participatory research to formulate the decision rules for the planting of cereals in relation to rainstorm events and soils and the movement of small ruminants for grazing. The models are used to estimate the dimensions of the small ruminant "feed gap" in good, average, and poor rainfall years in an area on the northwest coast of Egypt and to examine the potential for rangeland improvement and the introduction of fodder shrubs on feed resources.

The study indicates that small ruminant production relies on purchased feeds, even in a year of good rainfall. More barley is consumed than produced in all years, with only two of three agroecological zones showing a barley surplus in a good year. Average rainfall years exert more pressure on the system, as indicated by the level of hand-feed use, than poor ones because in the latter case many animals are removed from the area for drought grazing in the Delta. The GIS database was used to determine the potential in the area for rangeland improvement and the introduction of fodder shrubs as a substitute for purchased concentrates. About half of the rangeland in the area has soils and water accumulation to allow improvement. The introduction of *Atriplex spp.* interplanted in barley fields could reduce concentrate use by almost half in good rainfall years, but would contribute one quarter or less in average and poor years.

INTRODUCTION

Agricultural activity in semi-arid lands in the West Asia – North Africa (WANA) area is dominated by range - dependent small ruminant production systems. Sedentarization and other forces have led to increasing small ruminant populations, expansion of rainfed barley into marginal lands, degradation of rangeland, and an increasing dependency on purchased feeds (FAO, 1995). A variety of technological solutions have been proposed to address this "feed gap" and reduce natural resource degradation (Haddad and Tutwiler, 1994) to be adopted by producers. Solutions must be technically appropriate for their productions systems and recognize their biophysical and socio-economic resource constraints.

It is now widely recognized that participatory-based natural resource management and agropastoral development activities have significantly greater potential for sustainable results (Waters-Bayer, 1994). A critical problem in such projects is the challenge of integrating in a practical, cost-effective manner, the wide range of necessary formally and informally gathered, quantitative and qualitative biophysical and socio-economic information to ensure that needs are met, constraints identified, and practical solutions are generated.

The research addresses this problem by the use of a GIS database of biophysical and socio-economic information, coupled with simple spreadsheet models at the commodity and household scales, which describe the main elements of current production systems under simplified "good", "average" and "poor" rainfall conditions in a study area on the NW Coast of Egypt. This can be used both in diagnosis and to produce a preliminary evaluation of possible technological development options at the household level and, by aggregation, a variety of other scales in the area. In this paper, the methodology for database development is outlined and the databases used to examine the dimensions of the small ruminant feed gap and provide a preliminary evaluation of the potential for rangeland improvement and the impact of the introduction of fodder shrubs as a substitute for purchased feeds.

CONTEXT

The study area comprises two watersheds (Wadi Naghamish and Wadi Garawla) 270 km west of Alexandria. Mean annual rainfall is 144 mm with a coefficient of variation of 45% and high spatial variability. There are three agroecological zones: *Zone 1* (coast – 5 km inland) has the deepest soils and highest rainfall; production systems are predominately orchards (figs and olives), with cereals and some rainfed vegetables. *Zone 2* (5 – 15 km) has fewer orchards and more cereals and small ruminants. *Zone 3* (15 – 25 km) is dominated by livestock production, small ruminants, and to a lesser extent camels, with cereal production. Total Bedouin population is approximately 1800 in 107 extended households. The formerly semi-nomadic population began has becoming sedentary in the 1960s, and the process is now complete. With sedentarization, the small ruminant population has grown considerably in the past three decades, and the natural environment degraded.

The small ruminant production system in the area is based on winter rangeland grazing, movement of flocks to the cereal fields for stubble grazing after harvest, and several months on hand feed (barley and concentrates) prior to returning to the range again. In drought years, many animals are moved to irrigated areas at the fringe of the Nile Delta to survive on cultivated forage or residual vegitation.

Estimating Animal Numbers and Feed Consumption

To generate the small ruminant feed budget under each of the three rainfall scenarios, it is necessary to estimate the number of animals in the system in each rainfall-year type and the local and purchased feeds consumed. The number of flocks and their sheep/goat composition under the "good" rainfall scenario were determined from an initial survey of all households, supported by key informant interviews. Adjustment factors based on such interviews were used to estimate the numbers for the other rainfall scenarios. A summary of total animal numbers is provided in Table 1. Of the 80 flocks in the study area, 72% are mixed sheep and goats, 21% are goats only and 6% sheep only. The flocks ranged in size from less than ten animals to over 500.

Table 1. Number of small ruminants and movement.

Zone	Good Year	Move Outside	Average Year	Poor Year
	------No.-----	----%----	----No.----	----No.----
1	2801	69	2370	2171
2	2103	68	1691	1539
3	1010	43	828	760
Total	5914	64	4890	4469

Many Bedouin move all or some parts of their flocks for grazing, depending on rainfall, flock size, and flock composition. Key informants in each zone identified the grazing resources used both range and cereal stubble within and outside the study area and the differential use of these resources by flock size and composition, as well as periods on hand-feed. The percentage of animals which move outside their zone for grazing remains approximately the same in the different rainfall years; however, the time spent outside is longer in "good" years.

To determine feed consumption, feed calendars (Goodchild et al., 1994) were constructed with key informants to determine the types and quantities of hand-feed consumed daily per animal and the percentage of the animal's total daily diet derived from grazing rangeland or cereal stubble. For each flock type in each location, hand-feeds were converted to Scandinavian Feed Units (FU) to allow for comparison and aggregation.

Hand feed consumption (excluding straw) by small ruminants in each year type for each flock type generated from the feed calendars and animal numbers is shown in aggregate form in Table 2. In addition to barley grain, hands feed comprise manufactured concentrates and maize, which is used primarily for goats. Total hand-feed consumption was highest in Zone 1, reflecting the size of the animal population, but the maximum consumption occurs in an "average" rainfall year rather than "poor", since in that type of year production of cereals and annual rangeland vegetation is reduced. The lower total for the "poor" year is caused by flock components being moved to drought grazing on the irrigated lands adjacent to the Nile Delta.

Table 2. Small ruminant hand feed consumption in various years

Zone	Year	Barley Grain	Maize	Concentrates	Total
			---------------------------Feed Units----------------------------		
1	Good	223609	0	75261	298870
	Average	32839	126401	307703	466942
	Poor	0	0	339785	339785
2	Good	63363	0	75726	139362
	Average	154604	54645	176831	386080
	Poor	106159	0	146850	253008
3	Good	20303	0	45196	65498
	Average	41832	0	39589	72421
	Poor	24610	0	154289	178899
Total	Good	307547	0	196183	503730
	Average	229275	181046	515123	925444
	Poor	130769	0	640923	771691

Estimating On-Farm Cereal Production

The principal on-farm feed crop is barley and wheat based on run-off cultivation with the area planted each year and the proportion planted to barley and wheat varying each year in relation to rainfall conditions and soil type, as well as other factors such as availability of seeds and personal circumstances. Given the limited land base and variability in precipitation, Bedouins attempt to maximize the cereal area planted each year to support their small ruminant flocks.

Bedouin cereal-planting decisions are largely determined by the amount/ intensity of rainstorms, their timing of occurrence, and the type of soil in their cereal land. To estimate the area planted under each rainfall year scenario, Bedouin indigenous knowledge was employed. Local terms for rainstorm events were ascertained. Two storm sizes were found to be critical: *Sale,* 8 – 14 mm, and *Salezein,* 15 mm+, their quantitative values being determined from rain gauge records. For soils, the Bedouin nomenclature was determined by participatory transects and participatory mapping of selected areas. A complete Bedouin soils coverage for the study area was produced from a SPOT 20 m. XS image using the participatory mapping as training sites. The Bedouin soil type for each cereal field was then determined by GIS overlay of cereal fields and the area of each type calculated.

To relate planting decisions to the rainstorms and soil type, decision-tree models (Gladwin, 1989) were constructed with key informants in each zone, relating storm timing and intensity to soil type. The resulting models were applied to the cereal field data to estimate the area planted in each zone under the three rainfall scenarios. Data on yield of barley by Bedouin soil type for these scenarios was collected from key informants in each zone and used to generate estimates of total production.

The Feed Gap and its Dimensions

The overall dimensions of the "feed gap" in the study area are indicated by adding the deficit/ surplus in barley production to the consumption of concentrates and maize; an overall barley deficit occurred in all three rainfall-type years. The surplus in Zones 2 and 3 in a "good" year being offset by the deficit in Zone 1. When concentrates and maize are included, the total deficit increases twofold in an average year. The difference between barley production and consumption reflects the importance of transfers in the system from other areas of the northwest coast, either in the form of purchased grain, or by Bedouin share-harvesting for a percentage of grain and straw in the main cereal producing areas west of Marsa Matrouh.

In order to estimate the potential impact of rangeland improvement and fodder shrubs addressing the current feed gap using the project' GIS databases, two activities are explored under the three rainfall scenarios: rangeland improvement supported by some form of water harvesting and the interplanting of *Atriplex* spp in cereal fields.

Potential for Rangeland Improvement

The area with potential for rangeland improvement in the study area was estimated using GIS overlay procedures. Three criteria are used; slope, soil depth, and water accumulation. For slope, areas less than 5 degrees are suitable for water harvesting (FAO, 1995). Shallow soils with depth less than 30 cm were excluded. Water accumulation was problematic because of a lack of directly measurable data. Flow accumulation (ESRI, 1996) as generated from a Digital Elevation Model (DEM) was substituted. However, this assumes that all rain becomes runoff with no loss by interception, infiltration, or evaporation. The flow accumulation values generated were categorized simply as low, medium, and high.

Currently cropped land (orchards and cereal fields) were excluded and the values for slope, soil depth, and flow accumulation were combined to generate an overall value for potential improvement of rangeland on a scale of 1 to 5. Only Classes 3 through 5 are considered as having potential. Overlay with parcel boundaries permits estimation of the area of each parcel which can be improved, and by aggregation Zone 1 and study area totals.

The analysis indicates that 42% of the 5658 hectares of rangeland in the study area could be improved based on the criteria selected. However, 54% of the improvable area is communal *Alia* grazing, which, if improved, might face problems either of over-use or of possible individualization. Of the land presently belonging to individual households, 60% of rangeland in Zone 3 has potential compared with only 30% in Zones 1 and 2.

Interplanting of Atriplex in Barley Fields

The planting of *Atriplex* in widely separated rows in barley fields has the potential to provide feed for small ruminants during the autumn. For the purposes of this paper, the following assumptions are used. Given a feed value of 0. 35 FU/kg/DM after three years, *Atriplex* could produce about 0.5 kg/DM/shrub/year (Le Houérou, 1992), the equivalent of 0.175 FU per shrub. Planting at 20 m between rows (1947 shrubs/ha) would generate 170.45 FU/ha/year. These are very conservative yield estimates for the *purposes of demonstration only*; yields could be double those used here (Hakkim, M., 1998, *personal communication*). It is assumed that this shrub is most suited to Zones 1 and 2 and that the practice is adopted on all cereal land.

The comparisons are made only in terms of replacement of purchased concentrates and are shown in Table 3. In a "good" year, *Atriplex* could replace almost half the concentrates used in Zones 1 and 2; however, in "average" and "poor" years, this is reduced to approximately 10% in Zone 1 and 25% in Zone 2. The key element here as in other areas where fodder shrubs have been introduced, will be management of the resource to prevent destructive over-use, particularly under low rainfall conditions.

Discussion

Although based to a large extent on respondents' estimates of feed consumption by their flocks, the techniques used here provide a rapid means to estimate the magnitude and changes in the production and consumption of small ruminant feeds in a highly variable low rainfall system. The variability in feed budgets both within a small area, and especially between rainfall type years, indicates the importance of designing interventions to meet the varying circumstances of producers and their resource base. The differential pressures on feed resources as demonstrated in these budgets emphasizes the need to adequately inform producers of appropriate management techniques to avoid their inadvertent destruction. Finally, a balanced approach is necessary. It has been repeatedly demonstrated in small ruminant production systems in this type of environment that removal of one constraining element in the system, be it water or feed, has invariably places pressure on the others.

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