From weed to wealth? Prospects for medic pastures in the Mediterranean farming system of north-west Syria

Thomas L. Nordblom [a], David J. Pannell [b,*], Scott Christiansen [a], Nerses Nersoyan [a], Faik Bahhady [a]

[a] Pasture, Forage and Livestock Program, International Center for Agricultural Research in the Dry Areas (ICARDA),
P.O. Box 5466, Aleppo, Syria
[b] School of Agriculture, and Centre for Legumes in Mediterranean Agriculture (CLIMA), University of Western Australia,
Nedlands, W.A. 6009, Australia

Abstract

Medic (*Medicago spp.*) pastures are widely grown in rotation with dryland cereal crops in Mediterranean climate zones of Australia. Attempts since the 1960's to introduce this system to Mediterranean west Asia and north Africa (the native region of medic) have not lead to significant adoption; farmers in the region recognize medic, but as a weed and natural pasture plant. This first detailed economic evaluation of the rotational medic system was conducted using a whole-farm linear programming model based on the agricultural system of north-west Syria. The model represents in detail impacts of rotation on yields, labor requirements of alternative farm activities, availability of family and hired labor, subsistence income requirements, livestock feed sources and uses at different times and a choice of sheep stocking rates. Biological data for the analysis are based on a large six-year cropping and grazing experiment near Aleppo on terra-rossa soil with rainfall mainly in winter and averaging about 330 mm annually. The trial compared a dryland medic-wheat system and traditional two-year rotations of wheat with: fallow, watermelon, lentil and vetch. Results indicate that, given current prices and yields from the trial, medic is less profitable than traditional rotations. The model was used to investigate situations in which medic would be economically preferred. Selection of a medic rotation by the model was found to be particularly sensitive to the area of the farm and the price of labor. On small farms, labor availability per hectare is high, favouring the production of labor intensive crops such as lentil and watermelon. On larger farms, labor costs of these enterprises are substantial, increasing the relative profitability of medic, especially if labor prices increase. Interestingly, the relative desirability of medic is more sensitive to its impact on subsequent wheat crops than to the level of pasture production. We also found that modest increases in the prices of sheep products (especially milk) have a major impact on the economic performance of medic. These insights will allow improved focusing and targeting of future research and extension activities.

* Corresponding author.

1. Introduction

With a growing recognition of problems associated with use of agricultural fertilizers in the USA and Europe, there have been calls for increased use of rotational systems which include legume species to substitute for nitrogen fertilizer. In Mediterranean farming systems of the west Asia/north Africa (WANA) region and southern Australia, legumes are already widely grown in rotation with cereals. Legume species grown in these regions include lupin, field pea, medic and clover in Australia, lentil, chickpea, faba bean and vetch in the WANA region.

Medic is the generic name for numerous species of the genus Medicago. Medic-dominant pastures are widely grown in Australia in rotation with cereal crops (the so-called 'ley farming system') but are almost unknown as such in the WANA region where it is part of the native flora. Despite hopes that it would become important economically in WANA (e.g. Cocks, 1988), medic is still known by farmers in most of the region only as a weed or natural pasture plant.

Beginning in the 1960's, various extension and research projects were undertaken in attempts to introduce the ley farming system to the WANA region (Smith, 1987). In general, these have not led to adoption of the system. Various reasons have been put forward for this, including lack of adapted species (Radwan et al., 1978; Adem, 1974; Puckridge and French, 1983), a lack of nodulation by symbiotic nitrogen-fixing microbes (Bull, 1984) and inappropriate management practices, particularly in grazing (Springborg, 1986) and tillage (Chatterton and Chatterton, 1984). To these technical factors, Springborg (1986) added a range of human and social constraints such as land tenure and national agricultural policies in the region. Economic arguments have been notably absent from the literature, although they are clearly central to farmer decision making about legume pastures (McCown et al., 1988; Ewing and Pannell, 1987; Ewing et al., 1989). To date there has been no detailed economic analysis of medic pasture anywhere in the WANA region.

Here we conduct such an economic analysis for a particular area in NW Syria. Our aim is to provide guidelines and directions for future research and extension on ley farming. In addressing this aim, we assess the economic viability of substituting a medic pasture-cereal system for traditional crop rotations. We selected NW Syria for our analysis due to the availability of detailed data from a long-running rotation trial at ICARDA's Tel Hadya research station, near Aleppo (on terra-rossa soil, with average annual rainfall of 330 mm which is mainly received in Winter).

Part of our approach is to identify circumstances in which economics favour medic, so that we have a better understanding of which issues need to be addressed in targeting further research and extension work. The technical problems alluded to above are addressed in that we will determine just how productive the medic pasture and associated wheat crops need to be for the medic rotation to be more profitable than traditional alternatives.

In the following section, we outline the background, data and structure of the linear programming (LP) model used in the analysis. This is followed by presentation and discussion of results from the model, including an examination of their sensitivity to a variety of changes in model parameters.

2. Linear programming model

Our model has elements in common with the MIDAS model developed in Western Australia (Morrison et al., 1986; Kingwell and Pannell, 1987) as both deal with dryland crop and pasture (including medic) rotations integrated with sheep production in a Mediterranean environment. MIDAS has been used in Western Australia to analyse a range of issues relating to crop-pasture rotations (e.g. Pannell, 1987), legume crops (e.g. Ewing et al., 1986, 1987) and the value of nitrogen fixation by legumes (Pannell and Falconer, 1988). Although Western Australian and NW Syrian farmers face somewhat similar physical environments, Western Australian analyses are in no way applicable in Syria due to quite dissimilar

Table 1
Summary of linear programming matrix

	(n)	Rotation (ha) 7	Graze medic (kg) 4	Sell or feed crop outputs (kg) 46	Feed cottonseed cake (kg) 4	Shepherd (flock) 1	Ewes (head) 1	Milk sale (kg) 1	Lamb sale (kg) 1	Cull ewe sale (kg) 1	Hire or sell labor (days) 10	Family (–) 1	Credit or debt (SL) 10		Limit
Objective (SL)	1												1/−1		max
Land (ha)	1	1												L	16
Labor (days)	5	a			a	a	a	a			−1/1	−a		L	0
Cash tr (SL)	5	a		−a	a		a	−a	−a	−a	a/−a	a	1/−1	L	0
Crop outputs (kg)	11	−a		1										L	0
Medic tr (kg)	4	−a	1											L	0
Intake (kg)	4		1	1	1		−a							L	0
Energy (MJ)	4		−a	−a	−a		a							L	0
Protein (kg)	4		−a	−a	−a		a							L	0
Cotton sd limit (kg)	4				1		−a							L	0
Milk tr (kg)	1						−a	1						L	0
Lamb tr (kg)	1						−a		1					L	0
Cull ewe tr (kg)	1						−a			1				L	0
Family (–)	1											1		E	1
Shep limit (flock)	1					1								E	1
Ewe limit (head)	1					−a	1							L	0

Notes: 1. Numbers next to row/column headings indicate numbers of rows/columns in the complete matrix.

2. a and −a represent positive and negative coefficients, respectively.

socio-economic conditions (e.g. hundred-fold differences in farm size; very different market systems and prices).

Our model assumes sedentary sheep, maintained with feed from the farm and with no access to feeds or grazing from other areas, except purchased feeds. While this will not seem strange to Westerners (including Australians), it is not the case for many flocks in the WANA region. Animals are shepherded to common grazing areas and roadsides, and to graze crop residues in other farmers' fields, for free or at a price. Fencing of fields to control grazing is rare, and sheep are brought into a fold each night for protection. The model assumes control of grazing is by shepherd and that sheep stay on the farm all year round.

The objective of understanding the economics of medic pasture in NW Syria has required a team effort and contributions from several disciplines. Data have been drawn from six years of results from a large crop rotation and grazing trial (Smith, 1987), a concurrent survey of local livestock and feed markets, a local farm survey, and feeding and production data on Awassi sheep raised for milk and lambs. Simpler than MIDAS, yet capturing the complexity of the local farming system, this model is an important step in targeting on-farm research in Syria.

2.1. Model structure

Linkages between farm activities and constraints are defined in an LP framework for optimizing farm plans for crop rotation, labor use, crop sales and feeding, and feed purchases, as well as ewe numbers and diets across seasons of the year. The model maximizes whole-farm net returns to family land, labor, capital and management. The matrix includes 81 activity columns and 50 constraint rows. Only brief summaries of main features of the model are given here. A summary of the linear programming matrix is shown in Table 1.

Activity columns. Seven categories are defined in the model:

(1) Crop rotation activities: one for each of the seven crop rotations in the Tel Hadya trial.

(2) Feeding activities: season-specific options for grazing wheat stubbles, vetch and medic pastures; options for feeding conserved feeds such as wheat straw, vetch hay, seed and straw, lentil straw; and purchased feeds such as barley grain and cottonseed cake.

(3) Crop sales activities: one for each crop product such as grain, straw, stubble sales, fresh melon sales, etc..

(4) Sheep activities: each ewe in the breeding flock is one unit of the activity EWE which is linked directly to milk, lamb and cull ewe sales activities as well as an activity committing the labor for shepherding. Each ewe entering a farm plan is subject to a set of dietary limits and requirements which must be met in each season of the year.

(5) Labor market activities: one each for both hired labor and off-farm work for family members for each of five seasons.

(6) Farm family labor availability and cash needs, in each of the seasons, are expressed in a single activity.

(7) Cash-flow activities: one each for positive and negative flows in each of five seasons.

Constraint rows. Fifty constraints are defined to link and limit the activities in the whole-farm model matrix. The constraints come under nine main headings:

(1) Land constraint: Farm sizes of 16, 32 and 64 ha are considered since most farms in the area fall within or below this range. A survey showed that only 8% of farms have more than 80 ha. Model results for smaller farms were very similar to the 16 ha farm so they are not reported separately.

(2) Labor constraints: There is one row each for five 'seasons' of the year. Family labor may be supplemented with hired labor at times of peak need in some solutions of the model.

(3) Cash-flow constraints: One row each for five 'seasons' of the year link the production, purchase and sale activities to the objective function via accounting activities. Costs and prices appear according to their season in these rows, allowing season-by-season accounting for cash-flows.

(4) Crop product constraints (and transfers): Sales and uses of the various crop products are tied to production activities by transfer rows. Each of the seven crop rotations produces wheat grain and straw biomass. We assume a maximum of 80% of the straw biomass can be collected (for sale or feeding in other seasons) with 20% lost to shattering and trampling. If wheat stubble is grazed in summer, we assume a maximum of 75% can be consumed by sheep, with the remainder lost to trampling and shattering. Where stubble grazing is deferred until autumn, these losses increase to 50%. An alternative use of straw in the field is to sell it for grazing in late summer.

Lentil straw is generated as a by-product of the hand-harvested crop. It can be fed to the farmer's own sheep in any of the four feeding seasons, or sold to others, with quantities controlled in a single constraint. Fresh watermelon production is sold through a sales activity, controlled by a single transfer constraint.

The three options for use of a vetch crop after it has been established have their quantities limited in a single row. Medic pasture production and offtake are controlled by four rows in the matrix, one for each feeding season.

(5) Feed quantity and quality constraints for sheep: Limits on maximum dry matter intake, and minimum crude protein and metabolizable energy levels are defined in the model on a per-ewe basis, season-by-season. The model finds the least cost diets from the viewpoint of the whole-farm, balancing stored and purchased feeds with seasonal pastures and crop residues over time.

(6) Constraints on consumption of cottonseed cake: For each of the four feeding seasons, cottonseed cake cannot exceed 10% of the diet.

(7) Livestock product transfer constraints: A flock of Awassi ewes is assumed to have two main marketable products (milk and weaned lambs), and one minor product (culled ewes). Each of these has a sales activity linked to the EWE activity by a transfer row.

(8) Constraints on shepherd and sheep: For some runs of the model it is desirable to remove sheep, and the commitments of shepherding time, from consideration. This has the effect of freeing family labor for other uses on the farm or in off-farm employment. A constraint sets the level of labor use by sheep to appropriate levels for shepherding or to zero if sheep are excluded.

(9) The one-family constraint: The family's minimum cash needs for essential purchases are specified in the FAMILY activity which is constrained to exactly one unit. This activity also provides quantities of labor which can be supplemented with hired labor if necessary.

Table 2
Average yields of wheat and other species in the rotation trial

Wheat yield		Other species grown in rotation	
Grain (kg/ha)	Straw biomass (kg/ha)	Name	Yield (kg/ha)
2090	3890	Fallow	0
2158	4000	Watermelon (fresh)	1763
1584	2882	Vetch hay and	938
		vetch grazed residues	391
		or	
		Vetch seed and	729
		vetch straw	1562
		or	
		Vetch pasture	1558
1591	2504	Lentil grain and	1047
		lentil straw	1971
			Estimated offtake [a] (kg/ha)
1278	2649	Medic pasture (low stocking)	
		Winter	48
		Spring	454
		Summer	162
		Autumn	26
1246	2384	Medic pasture (medium stocking)	
		Winter	85
		Spring	668
		Summer	268
		Autumn	23
1386	2721	Medic pasture (high stocking)	
		Winter	92
		Spring	878
		Summer	348
		Autumn	4

[a] Medic pasture offtake based on estimates of daily intake and numbers of ewe-grazing-days.

2.2. Data

Only summaries of the most important data and assumptions can be given here. Full details on the model and data are given in Nordblom et al. (1992).

Medic pasture is assumed to be marketable only through the farmer's own sheep. Nutritive requirements for a productive Awassi ewe (giving 50 kg of fresh milk sales, 16 kg of lamb/yearling sales, and 6.3 kg of cull ewe live weight sales per

year) have been estimated in Nordblom et al. (1992). To these requirements have been added allowances to account for a complement of followers: rams, replacement ewe lambs and yearlings for the 20% of the ewe flock assumed to be culled or lost each year.

Nutrition is budgeted for four seasons of the year: autumn (October, November, December), winter (January, February), spring (March, April, May) and summer (June, July, August, September). Maximum limits on dry matter intake for a

Table 3
Nutritive qualities and prices

Product	Crude protein (% of DM)	Metabolizable energy (mJ/kg DM)	Average 1986–91 deflated price [a] (SL/kg DM)
Medic pastures in:			
Winter	20.0	10.0	NA
Spring	18.0	11.0	NA
Summer	10.0	8.0	NA
Autumn	18.0	9.0	NA
Vetch pasture (in spring)	20.0	10.0	NA
Stubble pastures after machine harvest of:			
vetch hay (summer)	6.0	6.0	NA
wheat (summer grazing)	4.0	6.0	0.8
wheat (autumn grazing)	2.5	5.0	NA
Wheat straw collected and chopped after machine harvest	3.0	5.5	2.4
Legume straws after hand-winnowing to separate seed from crops hand-harvested and threshed:			
Lentil straw	7.0	7.0	3.9
Vetch straw	7.0	7.0	4.3
Vetch hay (with leaves, pods and immature seed)	12.0	8.0	5.1
Concentrate feeds:			
Barley grain	12.0	12.8	6.6
Vetch grain	25.0	12.4	10.1
Cottonseed cake	37.0	11.5	8.6
Market products:			
Wheat grain	NF	NF	8.3
Lentil grain	NF	NF	11.4
Watermelon (fresh weight)	NF	NF	2.4
Milk (fresh weight)	NF	NF	15.8
Lambs (live weight)	NF	NF	65.2
Cull ewes (live weight)	NF	NF	48.5

[a] All prices in 1990 Syrian Lira: SL42 = US$1
NA = no available price; this pasture not for sale in the model
NF = non-feed commodities for sale from the farm
DM = dry matter; MJ = megajoules

ewe and its followers in the four feeding seasons are assumed at 175, 107, 170 and 216 kg, respectively. Corresponding minimum limits on crude protein intake are 11.1, 9.8, 14.8 and 10.5 kg, while those on metabolizable energy are 1161, 1139, 1626 and 1304 MJ, respectively.

The estimated levels of crop and pasture offtake over the six seasons (1985/86–1990/91) are represented as overall averages in Table 2 and in the model.

In most cases, crop yields were measured in the trial by quadrat samples just prior to harvest and averaged for each treatment over three replicates. Adjustments for handling losses were made. Pasture offtake was estimated from records of sheep grazing days and assumptions on intake per head per day.

Medic pasture is considered to be just one among many possible sources of feed in the model (Table 3). Nutritive value of the pasture varies across the seasons according to stage of growth. In the grazing trial used to measure pasture offtake, grazing was halted for all stocking levels when the seed bank in the medium stocked pasture was reduced to about 200 kg/ha. Thus, medic pasture was managed very conservatively.

Prices and opportunity costs of the various feeds come into play in the model's sheep diet formulations. The prices shown in Table 3 are averages of deflated series obtained in the six trial years.

2.3. Production costs and labor requirements

Cash budgets are specified in early summer (June, July) and late summer (August, September), (as well as autumn, winter and spring) for a total of five seasons. Detailed production costs were estimated for all crop and livestock activities; total cash costs for each enterprise are shown in Table 4.

Watermelon crop costs and yields were weighted according to the probability of conditions being suitable for watermelon production, with allowance for some costs being incurred even if no watermelons are produced. In the trial it was only possible to produce watermelons in three years out of the six; the other three years were too dry and fields were only cultivated. Vetch establishment and harvest costs are separated since there are three options for harvesting: grazing the crop, harvesting it for hay, or harvesting for seed and straw. Lentil crop costs are similar to those of vetch grown for seed and straw, with high labor requirements for hand harvesting.

Medic pasture establishment costs in Table 4 include 30 kg/ha of seed at a cost of 200 Syrian Lira (SL) per kg. Since the pastures will self-regenerate in subsequent seasons following wheat, establishment costs are divided by 10 for the low-stocking treatment, 8 for the medium and 6 for the high-stocking treatments. These reflect

Table 4
Production costs and subsistence cash requirements (1990 Syrian Lira)

Operation	Unit	Total	Autumn	Winter	Spring	Early Summer	Late Summer
Wheat establishment	ha	4055	3150	500	405		
Wheat grain harvest	t	1235				1235	
Wheat straw harvest	t	600					600
Fallow cultivation	ha	780	195	195	195	195	
Watermelon production and harvest ($\times 0.67$)	ha	2244		130	1186	130	797
Vetch establishment	ha	3030	3030				
Vetch harvest:							
Vetch hay	ha	1195			1195		
or							
Seed and straw	ha	2250			350	1900	
Lentil production	ha	6185	930	2700	355	2200	
Medic establishment	ha	7230	7230				
Family subsistence cash needs	farm	36000	9000	6000	9000	6000	6000

approximate frequencies with which re-sowing is needed.

Labor demands of all crop and livestock activities on the farm are considered separately from cash requirements in the model. Mean family size and composition found in a survey of farmers in the area was the basis for our assumption that three man days per day, plus childrens' labor during school vacation months, are available for work on the farm. Finally, labor requirements for shepherded sheep are accounted for: a large fixed commitment plus a small per-ewe requirement, varying across the seasons as the work shifts from straight shepherding in summer, to the individual handling that goes with lambing and milking in winter and spring. Detailed labor assumptions are given in Nordblom et al. (1992).

2.4. Implementation

The LP model was implemented with MARG, an 'active' form of model documentation software developed at the Western Australian Department of Agriculture (Pannell, 1990), through which multiple changes in matrix coefficients, prices or constraints can be made in spreadsheets and carried automatically into model solutions for sensitivity analyses and summaries. Through MARG, the LP solver AESOP (Murtagh, 1991) was invoked to complete several thousand runs of the model from which the results presented here were selected.

3. Results

3.1. Initial results

The profitability of each of the rotations included in the standard model is shown in Table 5. Each result is for a model solution in which the entire farm area of 16 ha is constrained to the specified rotation. The three sheep stocking rates on medic pasture were evaluated in separate runs of the model.

The results in Table 5 are based on average production parameters observed over the six years at Tel Hadya and average sale prices from the

Table 5
Whole-farm income for each rotation on a 16 ha farm.

Rotation	Stocking rate	Whole-farm profit (SL/year)
Lentil-Wheat	–	173 000
Watermelon-Wheat	–	142 000
Vetch-Wheat	–	140 000
Fallow-Weat	–	125 000
Medic-Wheat	High	97 000
Medic-Wheat	Medium	83 000
Medic Wheat	Low	79 000

market at Aleppo over the same period. Based on these parameters and prices, the most profitable rotation (by a substantial margin) is lentil-wheat. This is consistent with farmer practice in the area, where lentil-wheat is a common rotation.

Rotations of wheat with watermelon or vetch are of similar profitability, and both are observed in the study area. The next most profitable rotation is fallow-wheat, which is around 15,000 Syrian Lira less profitable than watermelon or vetch rotations on the 16 ha farm. This is consistent with the observation that fallows are rare in the area.

Finally, in this standard version of the model, the medic-wheat rotations are clearly the least profitable. Of the three stocking rates considered, the highest rate is most profitable. Apparently the highest stocking rate is not so high that pasture production is adversely affected. However even this high stocking rate gives an average annual profit which is 45,000 Syrian Lira less than that of watermelon-wheat and 75,000 Syrian Lira less than lentil-wheat.

Clearly farms similar to this version of our model farm are unlikely to choose to grow medic given the 'standard' production and price parameters observed during the trial years. An immediate effect of this analysis is that low wheat grain and low pasture productivity of the medic-wheat rotation have become the focus of new bio-physical experimentation. For example, an early maturing barley, replaced wheat on small plots in the 1991/92 season of the trial. Barley following medic appeared not to suffer as severe water stress as did wheat, and consequently the yield was higher. Other possible causes of low cereal

yields following medic (e.g. nematodes) are also being investigated.

Some factors in the model may change over time or between regions and some may be changed by research. A key question we wish to address is, under what scenarios would ley farming be an economically desirable land use. In addressing this question, we hope to identify where future research and extension should be targeted and to provide target yields and farm types for future research.

We identified the following areas for sensitivity analysis to investigate the impact of potential changes in knowledge, technology and government policies (e.g. wages, product prices).

(1) Wheat yields in the Tel Hadya trial were low after medic relative to some other rotations. Yields after medic may be improved by agronomic research for better pasture production and/or nitrogen fixation by medics.

(2) Medic offtake may be improved by research for better medic production or grazing management.

(3) Average farm size in the region is around 16 ha, but there is a wide range of farm sizes. As noted previously, our model results are insensitive to reductions in farm size below 16 ha; we present results for farms of 16, 32 and 64 ha, which are typical small, medium and large farm sizes for the area.

(4) Wage rates may increase as economic development proceeds, reducing profitability of crops such as lentil which have a high requirement for labor.

(5) Prices of wheat and sheep products are likely to vary over time due to changes in supply and demand as well as government policies. Currently wheat prices received by Syrian farmers are above world prices; we investigate a reduction to near 1991 world prices. Prices for sheep products (milk and meat) might be expected to increase with continued economic development; we investigate the impacts of an overall 20% increase.

3.2. Changed production under current prices

Tables 6 and 7 show the average annual level of total farm profit given current output prices

Table 6
Whole-farm income (1000 Syrian Lira) for traditional rotations given standard model assumptions

Farm area (ha)	Rotation			
	Fallow-wheat	Watermelon-wheat	Lentil-wheat	Vetch-wheat
16	125	142	173 *	140
32	224	251	299 *	233
64	403	457	542 *	404

* Highest whole-farm income.

and production costs. In Table 6 results are presented for three farm sizes (16 ha, 32 ha and 64 ha) for each rotation except medic. For each farm size, the profit maximizing rotation is marked with an asterisk. In these results it is the lentil-wheat rotation for each farm size.

Results for the medic-wheat rotation with high sheep stocking are shown in Table 7. No results are presented for low or medium stocking here or subsequently since they were invariably inferior to those of the high stocking rate. As well as three farm sizes, Table 7 includes results of sensitivity analyses for three levels of medic offtake and four wheat yields (in wheat crops following medic). The three medic yields correspond to the standard level (the average level estimated from grazing data), 150% of the standard level and 200% of the standard level. Wheat yields are

Table 7
Whole-farm income (1000 Syrian Lira) for medic-wheat rotation with high stocking rate

Farm area (ha)	Medic offtake (percent of average)	Wheat yield following medic (kg/ha)			
		1400	1600	1800	2000
16	100	97	114	130	146
	150	113	130	147	163
	200	127	144	161	178 *
32	100	184	216	249	281
	150	214	248	282	315 *
	200	244	277	311 *	345 *
64	100	350	415	479	542 *
	150	409	476	543 *	610 *
	200	468	534	601 *	668 *

* Medic-wheat rotation as profitable as best traditional rotation in Table 6.

ranged from about the level actually recorded (1.4 t/ha) up to a level comparable to the best of the other rotations (2.0 t/ha). The aim of this approach is to identify the increase in biological productivity of the rotation which would be necessary for it to become the most profitable.

The results are dependent on farm size. On small (16 ha) farms, pasture offtake would have to double and wheat yields increase by 0.6 t/ha before the medic-wheat rotation would give greater whole-farm income than lentil-wheat. On both 32 and 64 ha farms, slightly less spectacular productivity increases would be needed for medic-wheat to beat the best traditional rotation. For example, if wheat yields of 2.0 t/ha were achieved, a 32 ha farm would require only a 50% increase in medic production whereas a 64 ha farm could be advised to produce medic pasture even at current offtake levels.

The reason medic is nearer to being selected on larger farms is the cost of labor used to harvest lentil and, sometimes, vetch. This suggests that higher wage rates should be investigated.

3.3. Higher wage rates

It is quite plausible for wage rates to double (from 100 to 200 Syrian Lira per day) in the foreseeable future if economic development leads to growth in labor demand from expanding service and industrial sectors. Tables 8 and 9 show results for this scenario.

Under higher labor costs, the optimal traditional rotation on medium and large farms would switch from lentil-wheat to watermelon-wheat (Table 8). On small farms, family labor supply is generally sufficient to avoid the need for this change. For this reason, medic is still relatively unprofitable on small farms, even with dramatically increased production (Table 9). On medium and large farms, however, only modest production increases would be needed for medic to be as profitable as watermelon.For example, on a 64 ha farm, as little as 1.6 t/ha of wheat would be sufficient to bring medic-wheat within 1,000 Syrian Lira of the profitability of watermelon-wheat, even with no increase in pasture offtake.

Table 8
Whole-farm income (1000 Syrian Lira) for traditional rotations given hired labor wage doubled to SL 200/day

Farm area (ha)	Rotation			
	Fallow-wheat	Watermelon-wheat	Lentil-wheat	Vetch-wheat
16	125	142	167 *	138
32	222	243 *	238	192
64	385	405 *	373	303

* Highest whole-farm income.

Table 9
Whole-farm income (1000 Syrian Lira) for medic-wheat rotation with high stocking rate given hired labor wage doubled to SL 200/day

Farm area (ha)	Medic offtake (percent of average)	Wheat yield following medic (kg/ha)			
		1 400	1 600	1 800	2 000
16	100	97	114	130	146
	150	113	130	147	163
	200	127	144	161	178 *
32	100	184	216	249 *	281 *
	150	214	248 *	282 *	315 *
	200	244 *	277 *	311 *	345 *
64	100	339	404	466 *	527 *
	150	396	462 *	528 *	594 *
	200	452 *	518 *	584 *	651 *

* Medic-wheat rotation as profitable as best traditional rotation in Table 8.

Overall it appears that medic is a realistic prospect on medium and large farms if wages do rise substantially enough. Depending on the level of wage rise or other price changes, our model can indicate to scientists the level of biological productivity necessary for medic to be economically preferred.

3.4. Lower wheat prices

Results for a substantial lowering of wheat prices (ceteris paribus) are shown in Tables 10 and 11. Under this scenario, the profitability of the non-wheat phase increases in relative importance. Lentil-wheat remains the profit maximizing traditional rotation on all farm sizes (Table 10). The prospects for medic under this scenario are reduced (Table 11); the productivity increases

Table 10
Whole-farm income (1000 Syrian Lira) for traditional rotations given wheat grain price reduced to SL 4.5/kg

Farm area (ha)	Rotation			
	Fallow-wheat	Watermelon-wheat	Lentil-wheat	Vetch-wheat
16	56	71	120 *	88
32	85	107	193 *	128
64	126	170	331 *	194

* Highest whole-farm income.

Table 11
Whole-farm income (1000 Syrian Lira) for medic-wheat rotation with high stocking rate given wheat grain price reduced to SL 4.5/kg

Farm area (ha)	Medic offtake (percent of average)	Wheat yield following medic (kg/ha)			
		1 400	1 600	1 800	2 000
16	100	51	61	71	80
	150	67	77	87	97
	200	81	92	102	112
32	100	92	111	130	149
	150	122	143	163	183
	200	152	172	193 *	213 *
64	100	166	205	242	278
	150	225	265	306	346 *
	200	284	324	364 *	404 *

* Medic-wheat rotation as profitable as best traditional rotation in Table 10.

Table 12
Whole-farm income (1000 Syrian Lira) for traditional rotations given sheep product prices increased by 20 percent

Farm area (ha)	Rotation			
	Fallow-wheat	Watermelon-wheat	Lentil-wheat	Vetch-wheat
16	125	142	173 *	140
32	226	258	299 *	244
64	430	480	543 *	456

* Highest whole-farm income.

Table 13
Whole-farm income (1000 Syrian Lira) for medic-wheat rotation with high stocking rate given sheep product prices increased by 20 percent

Farm area (ha)	Medic offtake (percent of average)	Wheat yield following medic (kg/ha)			
		1 400	1 600	1 800	2 000
16	100	119	136	153	170
	150	144	161	178 *	195 *
	200	168	185 *	202 *	220 *
32	100	226	260	294	328 *
	150	276	310 *	344 *	378 *
	200	325 *	359 *	394 *	428 *
64	100	434	501	568 *	634 *
	150	533	600 *	667 *	733 *
	200	631 *	698 *	765 *	832 *

* Medic-wheat rotation as profitable as best traditional rotation in Table 12.

necessary for medic to surpass the profitability of lentil are increased (cf. Table 7).

3.5. Higher sheep product prices

Finally, results for a 20% increase in prices for sheep products (ceteris paribus) are shown in Tables 12 and 13. This modest increase leaves lentil-wheat the most profitable rotation under measured production levels for medic-wheat, but brings medic-wheat very much closer to being the preferred rotation. On medium and large farms, the effect on productivity targets for medic-wheat is similar to that for a 100% increase in wage rates (cf. Table 9). Wage rates had no impact on small farms due to their lower absolute labor requirement, whereas higher prices for sheep

products do improve the position of medic pasture on small farms.

In the longer term, price increases greater than the 20% investigated here might easily occur. In this case, a major role for medic pasture in NW Syria would seem assured. If such price rises were accompanied by higher wage costs, medic would become very desirable to many farmers in the region.

4. Discussion

The prospect of medic pasture succeeding in this farming system is strongly influenced by the profitability of alternative rotations. Under current conditions in areas of NW Syria similar to Tel Hadya, chances of the medic-wheat option

having a major economic impact on the majority of farms appear slight.

We have, however, identified a number of potential changes to current circumstances which would make it much more likely for medic-wheat to be the preferred land use for a significant number of farmers. Primarily, these changes are an increase in wage rates (which would reduce the profitability of key traditional rotations) and/or an increase in prices for sheep milk and meat, which would raise economic returns from pasture. If these both these changes occurred, no further improvements in medic-heat productivity would be needed for them to be economically preferred on medium and large farms.

We have identified farm size as a critical issue for medic. In the region modeled, only on larger farms are the labor costs of traditional rotations sufficient to reduce their profitability to near that of medic-wheat. This consideration coincides with several other factors favouring larger farms for the medic system, including the desirability of exploiting the status and authority of large land-holders, the greater availability of resources for experimentation, the higher average level of education of farmers on larger farms and the firmer ties to government of these farmers (Springborg, 1986).

The other potential change favouring medic is an improvement in productivity of the medic-wheat rotation. Under current conditions, the required improvements in medic-wheat productivity seem too large to bridge the profit gap, but even modest changes in labor costs or sheep product prices may reduce the required productivity increase to a feasible level. Preliminary trial results with barley following medic suggest that medic-barley rotations may be more profitable than medic-wheat.

Another variable factor is the region considered in our analysis. Specific quantitative results which we have presented are highly site-specific. Even within NW Syria, the relative profitability of the various rotations we have considered would vary widely according to climate and soils. It seems likely that dryer regions, in which lentil does not perform nearly so well, may offer better economic prospects for adoption of medic. In

other parts of the WANA region, rotations of wheat with a legume (even a legume crop) are relatively uncommon (Springborg, 1986) so from the point of view of farmer familiarity with legume rotations, NW Syria may be a relatively favourable area for adoption of medic by farmers. On the other hand, average farm size in Syria is smaller than for most other countries of the region (Springborg, 1986), a factor which we have shown decreases the desirability of medic. In regions where medic does not have to compete economically with lentil, our observation about the greater prospects for medic in drier areas will not necessarily apply.

5. Concluding comments

No Syrian farmer to date has been independently able to adopt a medic-wheat rotation. No medic seed is available on the local market and no locally adapted seed has been released by the Syrian Ministry of Agriculture and Agrarian Reform (SMAAR) nor multiplied for farmers' use. These are still early days for this technology in Syria. Further, most Syrian farmers have been required by law to allocate their land to crops in proportions specified in a central planning scheme which accounts for different growing conditions in the various farming zones of the country. Although enforcement of the agricultural plan is problematic, medic pasture has not been part of the plan and cannot be promoted widely among farmers until it is.

Our analysis has provided: (a) indications of circumstances where medic pasture is most likely to be of economic benefit, allowing better targeting of research and extension in future, (b) productivity targets for researchers for the medic-wheat rotation, and (c) clues as to why medic has not yet been widely grown throughout the region. It is clear that, in certain circumstances, medic pastures may improve profitability of farms in NW Syria. It is equally clear that medic will not be suitable in all situations. Particularly on small farms with plentiful labor, even dramatic increases in productivity of the medic-wheat rotation (relative to levels observed in the Tel Hadya

trial) may be inadequate to warrant medic-wheat production. On the other hand, larger farms may benefit from medic pasture with quite modest productivity improvements, especially if wage rates and/or sheep product prices increase.

On-farm trials of medic-cereal rotations are planned in collaboration between ICARDA and SMAAR in which cooperating farmers are freed from the normal regulations imposed on their neighbours. Farmer selection for these trials is based on the results of this analysis: full-time farmers who own sheep and have large holdings in areas where high-value, labor-intensive rain-fed crops are, as a rule, less successful than elsewhere.

By necessity our study has had limitations in a number of areas. We have not addressed the impacts of yield or price risk on selection of enterprises or adoption of a new system. Pannell et al. (1991) found that in Western Australia income derived from pastures has a lower variance than that from the available crop options, so that risk averse farmers are attracted to pasture. In the minds of Syrian farmers, if such a benefit exists, it may be countered by the risks associated with adopting a new farming system, at least in the short run.

Use of a medic-wheat rotation is likely to improve soil nitrogen availability over time. Unpublished data from the Tel Hadya trial show gradual increases of soil N in medic-wheat and vetch-wheat plots through the years; lentil-wheat plots showed no change; watermelon-wheat and fallow-wheat showed declining soil N. Further research is needed to assess the potential economic contributions of N from well managed pastures and forage crops under NW Syrian conditions.

Because we relied on a particular field trial for our biological data, we were not able to evaluate stocking rates or rotations which were not included in the trial. It may be that higher stocking rates than the highest examined would increase the profitability of medic. Alternative rotations may also favour medic. In Australia, medic is often grown in phases of more than one year. The MIDAS model indicates that in many circumstances, a two-year medic phase followed by one

year of wheat is more profitable than the medic rotation examined in this study (Pannell and Bathgate, 1991). It is possible that the choice of rotations in the Tel Hadya trial biased results away from medic production.

Overall, the study has provided valuable guidelines for future research, and an indication that further effort to develop the medic pasture system for this region is warranted if it is well targeted.

References

Adem, L., 1974. Etude du comportment des medicago annuelles. Institut National Agronomique, Univ. Alger, Algeria.

Bull, B.C., 1984. Jordan-Australian Dryland Farming Project, Annual Report, 1983/84. Department of Agriculture, Adelaide, South Australia.

Chatterton, B. and Chatterton, L., 1984. Alleviating land degradation and increasing cereal and livestock production in north Africa and the Middle East using medicago pasture. Agric. Ecosyst. Environ., 11: 117–129.

Cocks, P.S., 1988. The role of pasture and forage legumes in livestock based farming systems. In: D.P. Beck and L.A. Materon (Editors), Nitrogen Fixation in Mediterranean Agriculture. ICARDA, Aleppo, pp. 3–10.

Ewing, M.A., Pannell, D.J. and Morrison D.A., 1986. The

place of lupins in the farm rotation: a whole-farm modelling approach. In: Proc. 4th Int. Lupin Conference, 15–22 August 1986, Geraldton, Western Australia, pp. 152–60.

Ewing, M.A. and Pannell, D.J., 1987. Development of regional pasture research priorities using mathematical programming. In: J.L. Wheeler, C.J. Pearson and G.E. Robards (Editors), Temperate Pastures: Their Production, Use and Management. Australian Wool Corporation/ CSIRO, Melbourne, Vic., pp. 583–585.

Ewing, M.A., Pannell, D.J. and James, P.K., 1987. The profitability of lupin:cereal rotations. In: R.S. Kingwell and D.J. Pannell (Editors), MIDAS, A Bioeconomic Model of a Dryland Farm System. Pudoc, Wageningen, pp. 82–90.

Ewing, M.A., Pannell, D.J. and Morrison, D.A., 1989. Pastures and profit in an Australian ley farming system. In: Proc. 16th Int. Grasslands Congress, Nice, France.

Kingwell, R.S. and Pannell, D.J. (Editors), 1987. MIDAS, A Bioeconomic Model of a Dryland Farm System. Pudoc, Wageningen, 207 pp.

McCown, R.L., Cogle, A.L., Ockwell, A.P. and Reeves, T.G., 1988. Nitrogen supply to cereals in legume ley systems under pressure. In: J.R. Wilson (Editor), Advances in Nitrogen Cycling in Agricultural Ecosystems. Proc. Advances in Nitrogen Cycling in Agricultural Ecosystems, Brisbane, Qld., 11–15 May 1987. CAB International, Oxford.

Morrison, D.A., Kingwell, R.S., Pannell, D.J. and Ewing M.A., 1986. A mathematical programming model of a crop-livestock farm system, Agric. Syst., 20: 243–268.

Murtagh, B., 1991. AESOP User Manual. Minos-Aesop Associates, Collaroy, New South Wales, Australia.

Nordblom, T., Christiansen, S., Nersoyan, N. and Bahhady, F., 1992. A whole-farm model for economic analysis of medic pasture and other dryland crops in two-year rotations with wheat in northwest Syria. ICARDA, Aleppo, 100 pp.

Pannell, D.J., 1987. Crop-livestock interactions and rotation selection. In: R.S. Kingwell and D.J. Pannell (Editors), MIDAS, A Bioeconomic Model of a Dryland Farm System. Pudoc, Wageningen, pp. 64–73.

Pannell, D.J., 1990. MARG, MP Automatic Run Generator, User Manual. Western Australian Department of Agriculture, Perth, 128 pp.

Pannell, D.J. and Falconer, D.A., 1988. The relative contributions to profit of fixed and applied nitrogen in a crop-livestock farm system. Agric. Syst., 26: 1–17.

Pannell, D.J. and Bathgate, A., 1991. MIDAS, Model of an Integrated Dryland Agricultural System. Manual and Documentation for the Eastern Wheatbelt Model Version EWM91-4. Miscellaneous Publication 28/91, Department of Agriculture, Perth, Western Australia, 162 pp.

Pannell, D.J., Kingwell, R.S. and Robinson, S.D., 1991. Farm level responses to lower wool prices under risk aversion. Paper presented 35th Annu. Conf. Australian Agricultural Economics Society, University of New England, Armidale N.S.W.

Puckridge, D.W. and French, R.J., 1983. The annual pasture in cereal-ley farming systems of southern Australia: a review. Agric. Ecosyst. Environ., 9: 229–267.

Radwan, M.S., Al-Fakry, A.K. and Al-Hassan, A.M., 1978. Some observations on the performance of annual medics in northern Iraq. Mesopot. J. Agric., 13: 55–67.

Smith, A., 1987. Productivity of the ley farming system. In: P.S. Cocks (Editor), Pasture, Forage and Livestock Program. Annual Report for 1986, ICARDA, Aleppo.

Springborg, R., 1986. Impediments to the transfer of Australian dry land agricultural technology to the Middle East. Agric. Ecosyst. Environ., 17: 229–251.