Technologies integration in Mediterranean rainfed conditions: A spatial perspective on the results from the MEDRATE project

De Pauw E.

in

Cantero-Martínez C. (ed.), Gabiña D. (ed.).
Mediterranean rainfed agriculture: Strategies for sustainability

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 60

2004
pages 269-281

Technologies integration in Mediterranean rainfed conditions: A spatial perspective on the results from the MEDRATE project

E. De Pauw
International Center for Agricultural Research in the Dry Areas (ICARDA),
P.O. Box 5466, Aleppo, Syria

SUMMARY – The MEDRATE project has generated a comprehensive dataset on production systems and technology testing from pilot areas in the Mediterranean region. This paper makes a synthesis of environments and production systems in the pilot areas, and demonstrates that they are representative for a wide range of agricultural environments in the Mediterranean region. The paper also confirms the strong linkages between production systems and environments, highlights the perception of drought and rainfall variability as a key environmental risk across all pilot areas, the importance of rural-urban interactions in guiding agricultural development pathways, and the need for a better awareness of the space-dependence, in terms of climatic, soil and terrain conditions, of some of the technologies studied.

Key words: GIS, agricultural environments, Mediterranean region, production systems.

***RÉSUMÉ –** "Intégration de technologies en conditions pluviales méditerranéennes: Une perspective spatiale sur les résultats du projet MEDRATE". Le projet MEDRATE a produit une base de données vaste sur les systèmes de production et les résultats d'expérimentations conduites dans des sites pilotes en Méditerranée. Cet article fait la synthèse des environnements et systèmes dans les sites pilotes, et indique qu'ils représentent bien un grand nombre d'environnements en Mediterranée. Cet article confirme les relations fortes entre systèmes et environnement, accentue la sécheresse et la variabilité des pluies comme facteur de risque dans tous les sites pilotes, l'importance des interactions rurales-urbaines et le besoin d'une meilleure connaissance de la variabilité spatiale des climats, paysages et sols, avant de faire des recommandations sur l'emploi de certaines technologies.*

***Mots-clés:** SIG, environnement agricultural, région méditerranéenne, systèmes de production.*

Introduction

The MEDRATE project has generated impressive data from a number of key pilot areas, which represent different agroecological and socioeconomic conditions in the Mediterranean region. Obviously the pilot areas are samples of a highly diverse region, but as will be demonstrated in the paper, the diversity within many of these pilot areas allows getting a good understanding of the interactions between environments, production systems and technologies in the Mediterranean region.

With the wealth of information compiled through the project, there is always the risk of getting bogged down in the site-specific and losing the overall perspective. In fact, after the initial results have been presented at the Zaragoza workshop in May 2003, it appears that the spatial dimension involved in technology integration remains under-appreciated and requires a redress. This "out-scaling" dimension of technology integration, where the results from the pilot areas could be applied in other areas, remains a challenge. To answer this question requires a spatial representation of similarity of agroecological and socioeconomic environments. Geographical information systems (GIS) are quite good in dealing with the issue of agroecological similarity, but are barely starting to get a grip on mapping production systems.

The second dimension of technology integration, probably the more important one, is the combination of the technologies, tested in the pilot areas, into packages that are suitable for different farmers and communities in different parts of the Mediterranean. How realistic is this idea, what would be the guiding principles, and through what approaches or methodologies could this goal be achieved?

The scope of this paper is too narrow for answering these questions, but it can provide some useful insight into the relationships between biophysical and socioeconomic environments on the one hand, and the Mediterranean production systems, on the other, which certainly have been established through much earlier work, and are now being confirmed through the pilot area studies. Basically this paper will provide a synthesis of the characteristics (environments, cropping and animal components, system problems) of the production systems in the pilot areas, and review whether existing conceptual frameworks for linking production systems, and their trends, to environments are still valid.

Environments and production systems of the pilot areas

This section provides summary descriptions of the production systems in the pilot areas. They are summarized in terms of environments, characteristics of cropping and animal with respect to environments, crop and animal production systems, and general system problems. For each pilot area a landform map and a climate diagram are given to represent the environments. The aim of these site summaries is to situate the pilot areas into the broader context of Mediterranean agricultural environments and systems, which has been described in a companion paper (De Pauw, 2004). The location of the pilot areas is shown in Fig. 1.

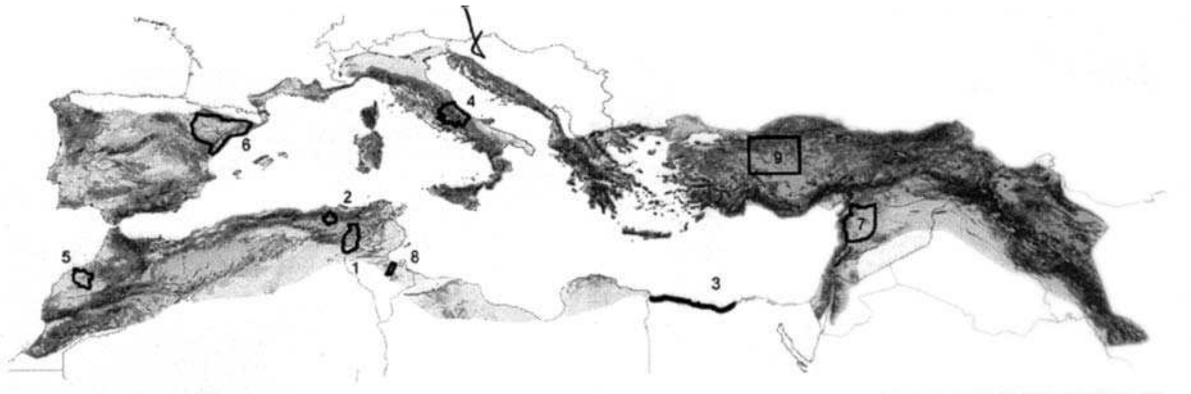

Fig. 1. Location of the pilot areas. (1: Bedessa, Algeria; 2: Constantine, Algeria; 3: NW Egypt; 4: Abruzzo, Italy; 5: Chaouia, Morocco; 6: Ebro Valley, Spain; 7: NW Syria; 8: Jeffara, Tunisia; 9: Ankara, Turkey).

Landforms

Figures 2 and 3 show the landforms for each of the pilot areas. These maps have been derived by clipping the Landform Map of CWANA and the Northern Mediterranean (Scheldeman and De Pauw, 2003) in a GIS. The legend of this raster map differentiates seven landform classes, of which three "plain" classes on the basis of elevation, and four classes of "dissected" landforms, based on the difference in elevation between neighboring pixels (Table 1). The pixel size of the raster map is 0.008333 x 0.008333 decimal degrees, which corresponds with 0.75 km^2 in Egypt, and with 0.64 km^2 in Italy.

Table 2 summarizes the relative occurrence of the recognized landform categories in the pilot areas. Landforms are strikingly diverse across pilot areas and include plains, hills, and mountains. The most plain-like landscape is situated in NW Egypt, the most mountainous in the Abruzzo region. The other pilot areas are in between, with either plains, or hills and mountains predominating. With the exception of the Egyptian pilot area, all pilot areas contain a high proportion of hilly areas.

Landforms, land use and production systems are intimately linked. If climatic conditions allow or water resources for irrigation are available, and soils have no severe salinity problems, plains invariably constitute high-potential areas for rainfed or irrigated crop production. Hills, and especially mountains, have more limitations for agriculture, particularly steep slopes and shallow, stony, or immature soils. For these reasons they are usually associated with less intensive land uses, such as natural grazing, forestry and tourism. However, some long-settled and densely populated hill landscapes can still be under intensive land uses, particularly terraced agriculture.

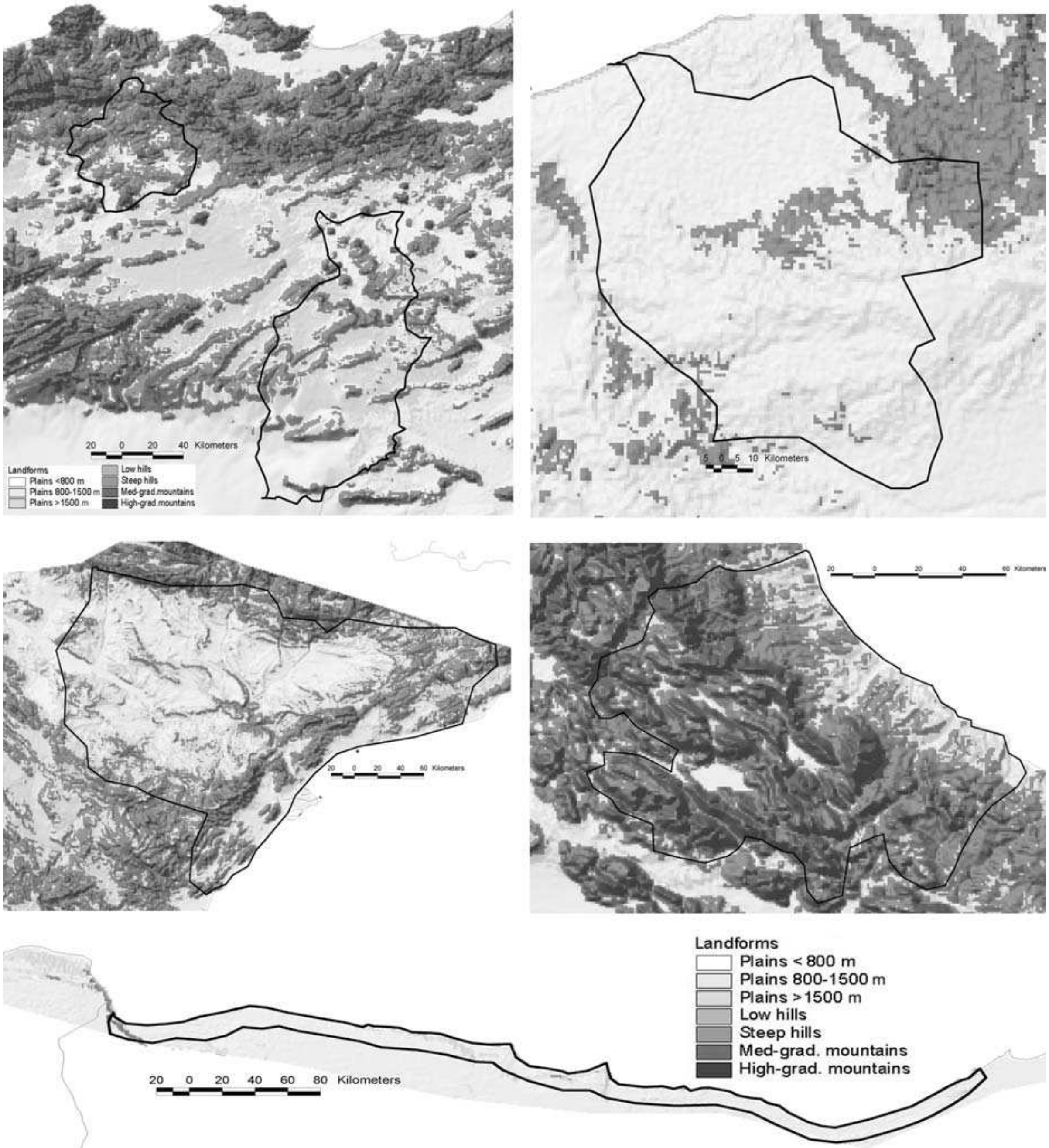

Fig. 2. Landforms of the pilot areas (1). Clockwise from top-left: NE Algeria (Constantine: left; Tebessa: right), Chaouia (Morocco), Abruzzo (Italy), Ebro Valley (Spain); bottom: NW Coast, Egypt.

Table 1. Landform classes

Landform class	Difference in elevation
Low-altitude plains (altitude < 800 m)	0-50 m
Mid-altitude plains (altitude 800-1500 m)	0-50 m
High-altitude plains (altitude > 1500 m)	0-50 m
Low hills	50-100 m
Steep hills	100-300 m
Medium-gradient mountains	300-600 m
High-gradient mountains	> 600 m

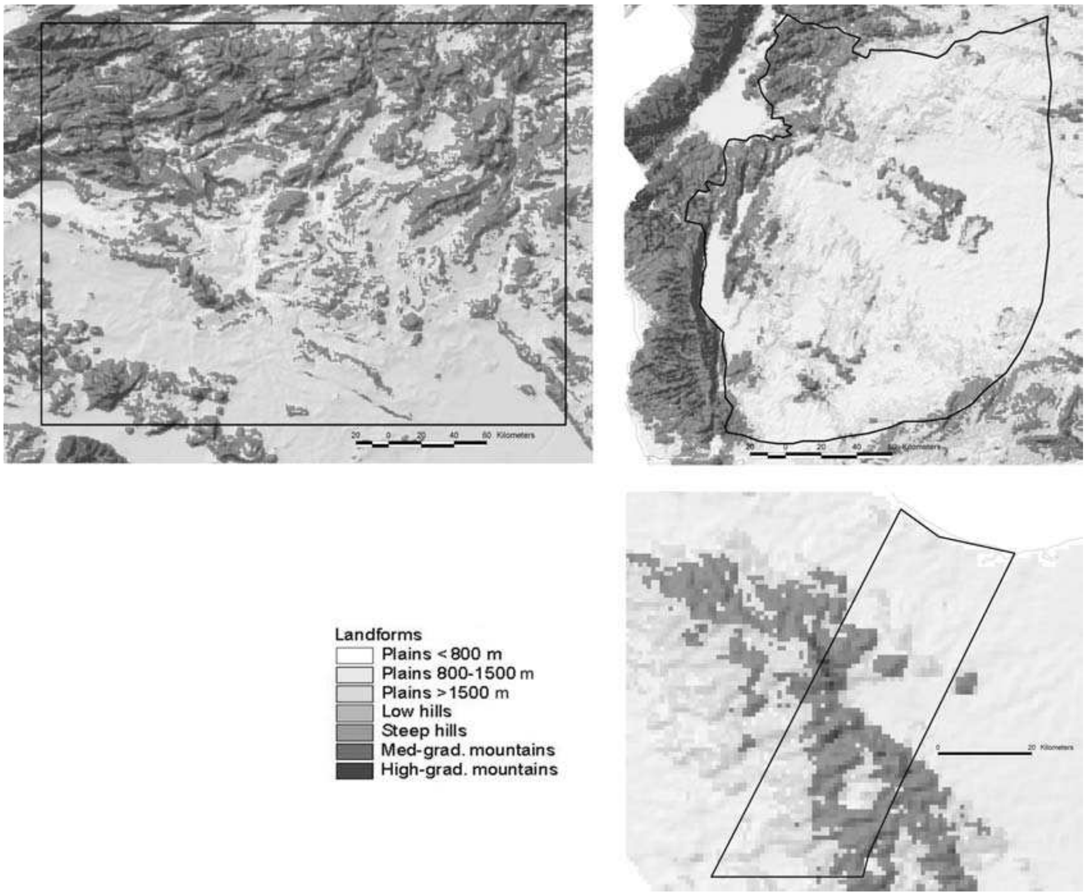

Fig. 3. Landforms of the pilot areas (2). Clockwise from top-left: Ankara (Turkey), NW Syria, Jeffara (Tunisia).

Table 2. Relative occurrence of landforms in the pilot areas

Area	Area (km^2)	Landforms (% of pilot area)						
		Plains <800 m	Plains 800-1500 m	Plains >1500 m	Low hills	Steep hills	Medium-gradient mountains	High-gradient mountains
NW Syria	30,666	55	0	0	27	16	2	0
Abruzzo (It.)	13,730	5	0	0	11	44	31	8
Ebro (Sp.)	38,802	29	0	0	34	33	3	0
Ankara (Tr.)	57,459	3	23	0	26	42	6	0
Jeffara (Tu.)	1,805	49	0	0	23	27	1	0
Chaouia (Mo.)	8,578	54	0	0	35	11	0	0
NW Egypt	6,255	91	0	0	8	1	0	0
Constantine (Alg.)	3,358	4	4	0	16	60	15	0
Tebessa (Alg.)	10,536	19	19	0	33	27	2	0

Climates

In Fig. 4 each pilot area is plotted by its position with respect to a precipitation and temperature axis. The temperature axis is represented in this diagram by growing degree day (GDD) units, being the mean temperatures accumulated throughout the year above 0 ºC.

Figure 5 shows representative climate diagrams for the pilot areas. Given the non-uniform climatic conditions in the Ebro Valley, a climate diagram is provided for the drier part of the Valley (Zaragoza) and the wetter part (Tarragona).

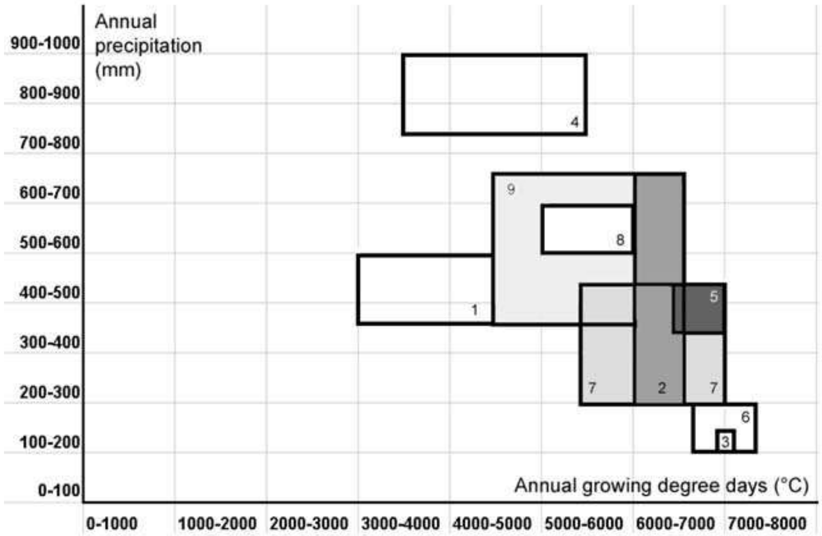

Fig. 4. Climatic conditions (precipitation and temperature) in the pilot areas. The size and position of each box in the diagram is determined by the range in annual precipitation and growing degree days [1: Turkey; 2: Syria; 3: Egypt; 4: Italy; 5: Morocco; 6: Tunisia; 7: Algeria (Tebessa); 8: Algeria (Constantine); 9: Spain].

Figure 4 indicates that the environments, covered by the pilot areas, encompass a wide range of precipitation (100-900 mm) and of temperature (3000-7500 GDD, or 8-21 ºC during the frost-free period). As annual precipitation decreases, there is a tendency towards higher average temperatures. The coldest pilot area is in Turkey, followed by Italy, the hottest in Egypt and Tunisia. The rainiest pilot area is in Italy, the driest in Egypt and Tunisia. The pilot areas in Turkey and Italy cover specific climatic domains. Climatic conditions in the Egyptian pilot area are entirely covered by those in the Tunisian pilot area. The same is the case in the pilot areas of Morocco and Constantine (Algeria), which are entirely covered by the climatic conditions in respectively Spain and Tebessa (Algeria). The climatic domains of the pilot areas in Syria and Tebessa overlap substantially.

Soils

The distribution of soil types in the different pilot areas is summarized in Table 3. The symbols used in this table are explained in Table 4. The figures have been derived from the digital version of the FAO Soil Map of the World (FAO, 1995) through standard GIS operations.

Table 3. Main soil types in the pilot areas†

Pilot area in	Soil 1	Soil 2	Soil 3	Soil 4	Soil 5	Soil 6
Algeria(1)	B (41)	X (33)	L (12)	I (14)		
Algeria(2)	X (43)	I,E (30)	B (14)	Y (4)		
Egypt	Y (41)	I (18)	DS††(14)	R (14)	Z (7)	
Italy	B (44)	E,I (25)	R (16)	L (11)		
Morocco	K (23)	B (21)	V (19)	L (17)	I (6)	R (5)
Spain	B (48)	Z (10)	R (10)	E (8)	L (5)	J (4)
Syria	X (45)	L (23)	I (11)	B (6)	Y (6)	
Tunisia	I (45)	Y (28)	X (9)	R (9)		
Turkey	X (47)	I (14)	B (9)	R (8)	L (6)	
All	X (29)	B (21)	I,E (16)	L (9)	R (8)	
Mediterranean region	X,Y (30)	B (11)	I,E (20)	L (5)	R (11)	

†Symbols for soil types are explained in Table 4. Soil 1: most important soil; Soil 2: second most important soil; etc. Figures in brackets indicate percentage of each pilot area.
††DS: sand sheets, mobile dunes.

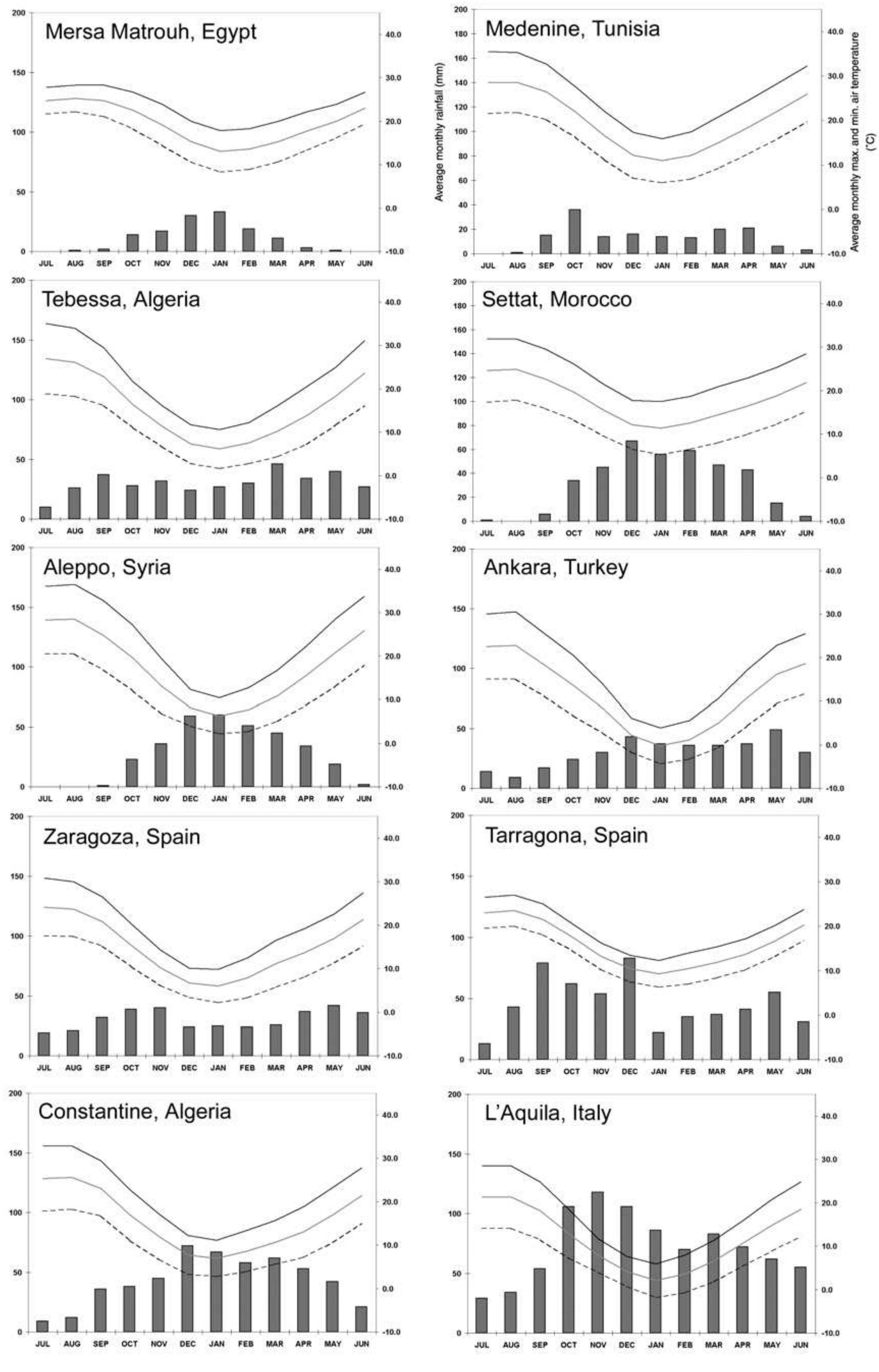

Fig. 5. Representative climate diagrams for the pilot areas.

Table 4. Main soil types in the pilot areas according to different classification systems

FAO, 1974	FAO, 1988 WRB, 1998[†]	Soil Taxonomy, 1994	Central Concept
Xerosols (X) Yermosols (Y)	Calcisols (Gypsisols)	Calcids (Gypsids)	Soils with high lime concentrations in the subsoil. Gypsisols have high subsoil gypsum concentrations
Lithosols (I) Rendzinas (E)	Leptosols	Lithic subgroups of different soil orders	Shallow soils
Cambisols (B)	Cambisols	Inceptisols	Moderately developed soils
Regosols (R)	Regosols	Orthents, Psamments	Poorly developed soils
Luvisols (L)	Luvisols	Alfisols	Non-acid soils with clay enrichment in the subsoil
Solonchaks (Z)	Solonchaks	Salids	Saline soils
Fluvisols (J)	Fluvisols	Fluvents	Soils formed on recent alluvium
Kastanozems (K)	Kastanozems	Ustolls	Lighter colored soils with fertile, well-structured, organic topsoil, enriched in lime or gypsum
Vertisols (V)	Vertisols	Vertisols	Darker colored cracking clays with (somewhat) deficient drainage

[†]World Reference Base for Soil Resources, as published by Deckers *et al.* (1998).

Across the pilot areas the Calcisols (X) are the most common soils in terms of total area. This is in agreement with the fact that they are the most typical soil of the Mediterranean zone (De Pauw, 2004). Particularly in the Tebessa pilot area, Syria and Turkey, they occupy nearly half of the area.

Cambisols (B) are very common, and occur together with Leptosols (I,E) in virtually all pilot areas. They occupy nearly half of the pilot areas in Constantine, Algeria, Italy, and Spain. Very shallow or stony soils (I,E) occupy nearly half the pilot area in Tunisia, and occupy 15-20% of the pilot areas in Algeria, Egypt and Turkey. Regosols, with marginal agricultural potential, are important minority soils in most of pilot areas.

The main agricultural soils of the region (L) occupy only a minority of the pilot areas, in accordance with their overall distribution in the region. Of all pilot areas, Syria has the highest share of Luvisols.

The pilot area in Morocco is well represented in soil types, which are agriculturally important (Kastanozems and Vertisols), but are only minority soils in the region. Typical alluvial soils, with high agricultural potential, are only well represented in the Spanish pilot area.

With the exception of the Cambisols, which are somewhat over-represented, the proportion of soil types in the pilot areas is fairly close to the relative importance of the major soils of the Mediterranean zone.

Production systems

In accordance with the terminology developed by Dixon *et al.* (2001), the following "model" types of agricultural systems occur in the Mediterranean zone:

(i) *Rainfed mixed*: highly diversified systems, with a wide range of rainfed crops, including tree crops (olives, fruits and nuts) and field crops (mainly wheat, barley, lentils, chickpeas, potatoes, sugar beet and faba beans). Terracing is common in hilly areas. Seasonal interaction with livestock, mainly sheep and goats, and use of crop residues and other fodder are common features.

(ii) *Dryland mixed*: less diverse than the rainfed mixed systems, with barley and wheat as main crops grown in alternation with single or double-season fallows or with legumes (lentil, chickpea).

Interactions with small livestock systems mainly take the form of barley and stubble-grazing and are stronger than in the previous system.

(iii) *Highland mixed*: dualistic land-use systems at higher altitude (1500-3000 m) with cropping pattern dominated by wheat and barley on arable land, and communal grazing on marginal land; mostly monoculture with occasional fallow, terracing common, sometimes supplemental irrigation.

(iv) *Irrigated*: traditionally along major river systems downstream from dams, but more recently also based on groundwater extraction. Systems can be either large-scale or small-scale and include a wide variety of crops and cropping patterns depending on temperature regime.

(v) *Pastoral*: systems based on the mobility of flocks and herds moving between more humid and drier areas, with the availability of grazing and water. Range resources under a wide precipitation range (typically 100-400 mm) are accessed.

(vi) *Sparse*: too dry for productive land use, which remains limited to opportunistic grazing following rainstorms.

With the exception of the *highland mixed* and *sparse* systems, which do not occur in any pilot area, all systems are represented. In addition, all pilot areas contain a mixture of different systems.

In all pilot areas cropping and animal production systems show adaptation to their environments. This is particularly obvious in relation to precipitation, usually the most limiting factor. As Fig. 6 indicates, production systems generally occupy narrow bands of the rainfall spectrum, although the latter may vary somewhat between pilot areas. The only exception is the irrigated systems, which occur within a broad rainfall range (Fig. 6).

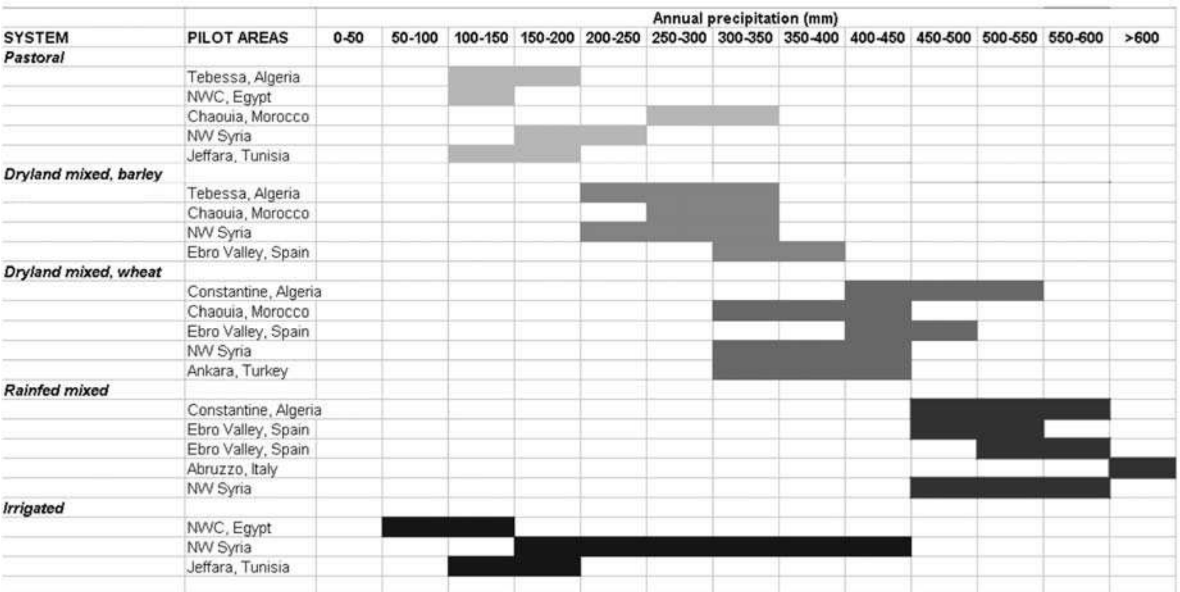

Fig. 6. Production systems in the pilot areas in relation to precipitation.

A first impression is that the distribution of production systems in the pilot areas confirms the "ICARDA framework" (ICARDA, 1989), which relates relative occurrence of major production systems to rainfall (Fig. 7). The arrows in fig. 7 show the main land use trends:

(i) Expansion of all rainfed cropping systems towards areas with lower rainfall.

(ii) Irrigation development across all rainfall zones.

(iii) Increasing pressure on rangelands through rangeland degradation, leading to an increase in the area of sparsely vegetated land, and through expansion of cropping systems.

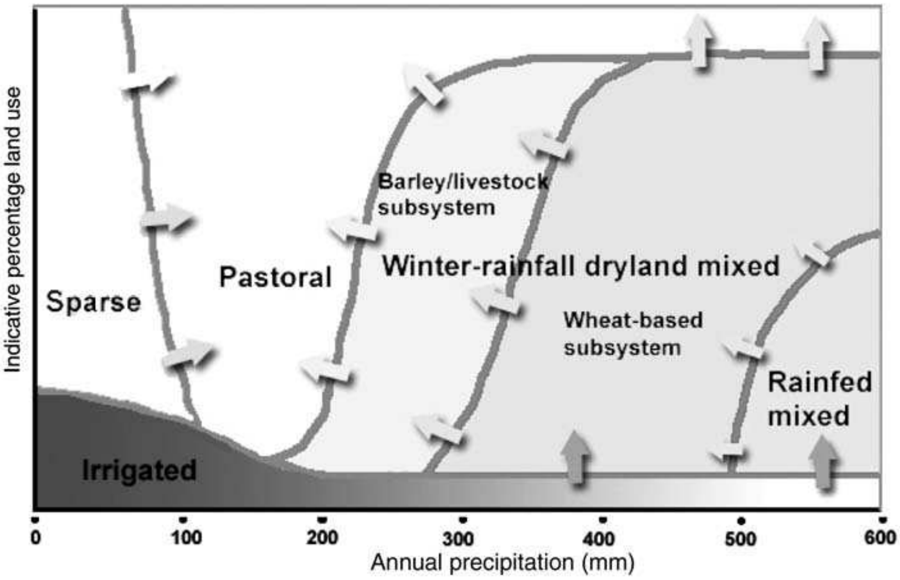

Fig. 7. Relationship between Mediterranean dryland agricultural systems and annual precipitation.

The increasing development of irrigation systems across all rainfall zones demonstrates its critical role in income generation, livelihoods improvement and systems diversification. In fact, even in the pilot areas in which irrigation is not shown in Fig. 6, it occurs on small scattered plots, usually from wells, and is a key factor in system intensification and cash crop generation.

Within this overall setting, there are some significant differences between the pilot areas of the Northern and Southern Mediterranean, in terms of system characteristics, land use trends, integration between cropping and animal systems and system problems.

The production systems in the pilot areas in the Ebro Valley and the Abruzzo, although in widely different biophysical environments, have the following social and economic characteristics in common:

(i) High-yielding, input-intensive systems (improved varieties, organic/mineral fertilizer, weed and pest control, mechanized operations).

(ii) Good road infrastructure.

(iii) Highly developed markets, no subsistence-farming component.

(iv) Highly dependent for economic viability on subsidies.

(v) Only minority of population involved in agriculture.

Populations are generally stable, but employment in agriculture may even further decline, due to aging of the farmer population, and job opportunities for the younger generation in urban agglomerations. Farm sizes vary considerably, and many small farms are, even with subsidies, not viable unless they intensify, shift their production to niche crops, or diversify into alternative income-generation activities, such as tourism.

There is a clear trend towards intensive livestock production, particularly pigs, poultry and cattle. Given the semi-industrial methods involved, the interaction with the cropping systems is low, and confined to the disposal of animal manure, or growing of barley as feedstock.

Although less arid than the Southern Mediterranean, drought remains a problem, even in the more rainy pilot area of Abruzzo, and is the source of production fluctuations, although rarely of the magnitude experienced in the Southern Mediterranean pilot areas.

In comparison with those in the North, the production systems of the Southern Mediterranean pilot areas in general have fairly contrasting characteristics:

(i) Low-yielding systems with medium to low input use.

(ii) Inadequate road network.

(iii) Imperfect markets, strong subsistence component.

(iv) Limited or no subsidies.

(v) Large population segments involved in agriculture.

This, however, may be an over-simplification of a more complex picture, which in fact shows production systems, agricultural populations and markets at different stages of development.

Table 5 provides a synthesis of the production systems, in terms of key indicators related to crop and animal productivity, socioeconomic characteristics, and environmental risk. Table 5 evidences both similarities and differences in the inputs-yield spectrum between the pilot areas in the South. In general, fertilizer use is sub-optimal, weed and pest control are poor, and use of improved varieties, adapted to local conditions, is limited. Agriculture is a more important sector of the economy, providing more income and employment, and being less dependent on subsidies. Marketing channels and access are less developed than in the Northern pilot areas. Whereas in the Northern pilot areas, similarities are high, the Southern pilot areas show greater diversity in their key indicators. While it is beyond the scope of this paper to explain these differences, some patterns are emerging.

Drought is a major risk for agriculture in all pilot areas, whether in the North or South, even in the ones with good rainfall. However, as the case studies of Egypt and Tunisia demonstrate, stabilization of production is possible on a limited scale, set by available water resources and terrain conditions, through water harvesting or supplemental irrigation, e.g. from wells.

Different pilot areas are in different stages of market development and farmer access to markets. The case studies from Syria, Turkey, Italy and Spain support the view that good market access is crucial for investment in inputs, and hence for high productivity.

Rural and urban environments not only interact through the markets, but also through permanent and temporary migration. In the Northern pilot areas, populations are fairly stable and agriculture is not a major source of rural employment. If urban centers are nearby, a process of sub-urbanization may take place, in which people with alternative income generation may gradually replace the agricultural population. In the Southern pilot areas, by contrast, populations are growing, some still strongly, and the growing urban environments may offer exit routes from agriculture through migration and off-farm income. However, if a nearby metropolis grows too strongly, as is the case in Ankara, it may impede the consolidation of farms and development of agriculture through land speculation.

Technologies and environments

Table 6. lists the technologies studied in the MEDRATE project. Although all technologies aim at improving productivity under specific environments, some are so much part of any technological package that they can be considered space-independent. Obviously, it is part and parcel of all agricultural improvements to have varieties adapted to each environment, to adapt cropping cycles and rotations to prevailing climates, to base fertilizer recommendations on soil tests, to control weeds, animal reproduction, etc., but such principles can be applied at any place. On the other hand, the feasibility of land and water management technologies is to a large extent or fully determined by the availability and quality of the natural resources, and can therefore not be taken for granted.

Table 5. Key indicators of the production systems in the pilot areas[†]

Theme	Factor	Constant., Algeria	Bedessa, Algeria	NW Coast, Egypt	Chaouia, Morocco	NW Syria	Jeffara, Tunisia	Ankara, Turkey	Abruzzo, Italy	Ebro, Spain
Crop production	Yield levels	L	L	L, M	M	M, H	L, M[††]	M, H	H	H
	Input use									
	Improved varieties	M	L	N.A.	M	M	M	M	H	H
	Fertilizer use	M	L	M	H	M	M	H	H	H
	Weed, pest and disease control	M	L	L	L	M	L	M	H	H
	Mechanization	M	M	M	H	M, H	L	H	H	H
Animal production	Intensity of production	L	L	L	L	L	L	M, H	M, H	H
	Interaction with cropping systems	H	H	H	H	H	H	H	M	L
Socio-economic features	Road infrastructure and market access	M	L	M	M	H	M	H	H	H
	Subsistence	M	H	M	M	M, L	L	M	L	L
	Subsidies	M	L	H	M	M	L	L	H	H
	Population in agriculture	H	H	M	H	M	H	L	L	L
	Farm sizes	L	M	L	L	L	L	L	L	M
	Population growth	M	M	M	H	H	H	H	L	L
	Out-migration	M	H	M	H	M	H	N	L	L
Environment	Drought impact	M	H	M	H	M, H	H, M[†††]	M	M	M

[†]N.A.: no data available. The symbols used are explained in the Appendix to this paper.
[††]Yield levels are low in rain-dependent areas (jeffara), higher in areas with water harvesting structures.
[†††]High in rain-dependent areas, medium in areas with water harvesting structures.

Table 6. Technologies studied in the MEDRATE project

Theme	Technology
Land and water management	Reduced tillage (including non-tillage)
	Water harvesting
	Supplementary irrigation
Crop production	Soil test calibration and fertilizer recommendations
	Seeding and planting techniques
	Improved plant material
	Weed control
	New crops and cropping systems
Animal production	Alternative and non-conventional feed resources
	Control of reproduction
	Breeding (selection and crossing)
	Processing of animal products (dairy, wool, hair, pelt)
	Forage conservation
	Range management and preservation

As indicated in an earlier section, soils show high spatial variability in the pilot areas. Minimum tillage is soil-dependent and blanket recommendations, that do not consider soil properties at local level, are not very useful. Particularly the clayey Luvisols or Vertisols require tillage for a good seedbed or to improve infiltration, whereas soils high in silt, are vulnerable to surface sealing and compaction.

Water harvesting can only be undertaken if water resources and terrain conditions allow. This means that precipitation should be sufficient to make it worthwhile collecting runoff, but if it exceeds a certain threshold (usually 250 mm) it makes more sense to keep the rain on the land. At the same time, the terrain should be such that there is a sizeable catchment area to deliver water directly to fields or storage systems, and that there is an area with sufficiently productive land where the water can be used. This means that slopes, soils and vegetation cover should be within acceptable ranges to meet the land suitability criteria for this particular technology.

The feasibility of supplemental irrigation depends primarily on available water resources, either from aquifers or from surface water, but also on precipitation. If precipitation levels are too low, systems require full irrigation, or, if too high, do no longer need it. Terrain may be an important factor in the case of surface water resources.

Conclusions

The pilot areas studied in the MEDRATE project offer a small but representative sample of the environmental and system diversity existing in the Mediterranean region. The major climates, landforms, soils, and production systems are well covered, with the exception of the highland mixed system.

The perception of drought and rainfall variability as a major environmental risk factor to agriculture, even in the higher rainfall areas, agrees well with climatic data. The data suggest the importance of the rural-urban interactions in the development pathways of agriculture, which in detail are complex, but in general are quite different between the northern and southern parts of the Mediterranean region.

There is a need for a better awareness of the space-dependence, in terms of climatic, soil and terrain conditions, of some of the technologies studied, and for appropriate land and water resource studies to guide the recommendations.

References

Deckers, J.A., Nachtergaele, F.O. and Spaargaren, O.C. (eds) (1998). *World Reference Base for Soil Resources. Introduction*, 1st edn. International Society of Soil Science (ISSS), International Soil

Reference and Information Centre (ISRIC) and Food and Agriculture Organization of the United Nations, Acco, Leuven.
De Pauw, E. (2004). Description of the Mediterranean agricultural environment. In: Final Report of the MEDRATE Project "Evaluation of Agricultural Practices to Improve Efficiency and Environment Conservation in Mediterranean Arid and Semi-arid Production Systems". *Options Méditerranéennes, Series B* (in press).
Dixon, J., Gulliver, A. and Gibbon, D. (2001). *Farming Systems and Poverty*. FAO and World Bank, Rome and Washington D.C., 412 pp. ISBN 92-5-104627-1.
FAO (1995). *Digital Soil Map of the World and Derived Soil Properties*. CD-ROM, version 3.5, November 1995. FAO, Rome.
ICARDA (1989). *Sustainable Agriculture for the Dry Lands. ICARDA's Strategy and Medium-Term Plans*. ICARDA, Aleppo, Syria.
Scheldeman, K. and De Pauw, E. (2003). Mapping landforms and soils of CWANA. *NRMP Annual Report*. Natural Resources Management Program, ICARDA, Aleppo, Syria.

Appendix

Abbreviations used for factor ratings in Table 5.

Yield levels – L: low; M: medium; H: high, in comparison to yield levels achieved under high-input conditions.

Use of improved varieties – L: local varieties; M: mixture of land races and improved varieties; H: improved varieties.

Fertilizer use – L: low (fertility restoration by fallow mainly); M: organic/some mineral fertilizer below recommended levels; H: high.

Weed and pest control – L: poor; M: some; H: high.

Mechanization – L: low, mainly animal traction; M: medium (some tractor-driven operations); H: land management and harvesting.

Animal production intensity – L: extensive grazing mainly; M: grazing + feedstock fattening, or dairy, improved pastures; H: industrial production (pigs, poultry, cattle).

Interaction with cropping systems – L: low (mainly manure disposal); M: barley and fodder crops for livestock; H: complementary use of high-potential and marginal lands, stubble grazing, barley and fodder feeding, feed blocks, use of manure on farms, etc.

Road infrastructure – L: inadequate for rapid access from the farm gate to local and distant markets; M: rapid access between local and distant markets, but not to the farm gate; H: rapid access to major markets from the farm gate.

Subsistence – L: most produce sold to markets; M: substantial retention for own consumption; H: most of the produce consumed by the producers.

Subsidies – L: none; M: some, e.g. in the form of controlled prices, subsidized equipment; H: high price or income support, infrastructural works.

Population in agriculture, population employed in agriculture – L: small proportion of the rural population (sub-urbanized countryside); M: high proportion of the rural population, but not majority; H: majority of rural population employed in agriculture.

Farm sizes – L: small (<20 ha); M: medium (20-50 ha); L: large (>50 ha).

Population growth – L: stable or declining; M: moderate (<2%); H: high (>2%).

Out-migration, rural to urban migration – L: low or small in-migration; M: out-migration in step with population growth – H: out-migration exceeds population growth; N: strong in-migration.

Drought impact – L: effects attenuated by high rainfall, low rainfall variability, or irrigation; M: moderate impact in the form of production declines; H: high impact in the form of crop failure.