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Full Length Research Paper

Farm diversity and crop growing practices in semi-arid regions: A case study of the Setif high plains in Algeria

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An analysis of farm diversity in semi-arid regions of Algeria shows the importance of differences in structure (size, crops and equipment), environment (climate zone) and organization (crop-livestock ratio) in understanding the strategic characteristics of local farms. Their economic orientation explains the use of resources and irrigation in particular. A crop management itinerary typology is proposed to categorize the different types of farms. The typology was developed step by step by combining the various cultural practices (time-frame, methods). The inputs use is diverse in the farms, some without inputs depending largely on the agro-ecological conditions to obtain a production. Supplemental irrigation, to ensure rather to increase the production, mainly concerns feed grain grown in the lower semi-arid zone, demonstrating the importance of local livestock rearing. Similarly, the highly variable grain yield relies more on annual rainfall and management methods than on the use of inputs. However, in areas with good rainfall where a good harvest is generally obtained, the economic profit varies between farms, without being directly related to farm management strategies used. In such unpredictable environmental conditions, the survival of these farms depends on the farmers' capacity to develop a diversified production system (livestock rearing, diversification of crops, feed grain, etc.) and adapt their farming methods to climatic variations. This present study opens up new areas of research, particularly by emphasizing the importance of "on-farm research" in agricultural research in Algeria.

Key words: Farms, on-farm practices, typology, grain crops, semi-arid, farm management.

INTRODUCTION

In Algeria, food production falls chronically short of food consumption. The usable agricultural area (UAA) is only eight million hectares resulting in a low average land size per person (0.30 ha) (Duboust, 1992; Bessaoud and Tounsi, 1995). Algerian agriculture is concentrated in a narrow band in the north of the country where a semi-arid climate prevails and rainfall is weak and irregular. The majority of farmers earn their living primarily from a combination of crop and livestock farming, although productivity is notoriously vulnerable (Benniou et al., 2003; Benniou, 2008) especially on grain farms (Jouve et al., 1995). Most of the government's intensive farming programs and the agronomic research conducted in these fields focus on the country's recognized productive zones, that is, those that receive the most rainfall (Djenane, 1997). Yet none of the country's crop-intensification policies have improved wheat production and the average national yield remains at 600 kg/ha (Duboust, 1992; Djenane, 1993; Lahmar, 1993)

The failure of these policies is at least partly due to the lack of a comprehensive approach to agricultural production conditions and a systemic approach in particular (Chehat and Charfaoui, 1999). It has been observed that

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there is very little on-farm research in Algeria. Little is known about adaptation of the farm management models proposed by research and development, nor the obstacles that prevent their adoption or how well they correspond to the environment and climate. Other unknown data are the diversity of the farmers' socio-economic situations and their production strategies and objectives (Benniou, 2008). This corroborates the long-time findings of farming systems research (FSR): there are frequent gaps between the development of a new technology and its adoption by farmers, largely due to the fact that researchers underestimate the fundamental differences in scale, focus and objectives that exist between the theory (agronomical, economic, etc.) used to create these technical innovations and the agricultural methods used by local farmers (farming practices, overall farm management) (Ruthenberg, 1971; Perrin et al., 1979; Fresco, 1984). The development of research methodologies in line with the FSR findings has led to considering the farm to be a complex management system (Collinson, 2000; Mc Cown, 2001, 2002; Carberry et al., 2002).

Like everywhere else in the world, the development of sustainable production systems is an important priority for Algerian agronomists. One of the first steps is to understand the relationship between the agricultural performance of production systems and farming practices (Coleno and Duru, 2005; Doré et al., 2007). The evaluation of economic performance of production systems (with scarce data available in our context) must take into account the diverse crop management practices (Cochet and Devienne, 2006) and the variable access to production resources, for example the purchase or lease of plots from one year to other (Gérard et al., 2001).

Our aim in this work was to contribute to understanding the diversity of farming systems and their relationships with the management practices and performances in the semi-arid regions of Algeria. Thus, we conducted a detailed analysis of farming practices to determine how farmers produce grain in the semi-arid regions of Algeria. Here, we will be looking at the Setif region (or *wilaya*). Based on the results of surveys of farms and individual plots, we will use specific concepts and methodology to analyze the farm structures and practices used to produce grain. Recommendations will be made for research and development. We will then discuss the possibility of continuing this type of “on-farm research”, which is still rarely used in Algeria despite what we consider to be an enormous need.

MATERIALS AND METHOD

We consider that the technical management mechanisms of farmers in semi-arid regions must first be understood before developing plans of action or new concepts and decision-making methods. This paper will therefore examine (1) the concepts used to analyze farm global management and agricultural practices and (2) the geographical context and survey methodology used in this study.

Conceptual approach to farm management and agricultural practices

This study is based on a systemic approach to farming. Following Capillon (1993), we considered the farm to be a system managed by the farmer and his/her family and we try to understand how the system functions, that is, "the sequence of decisions made by farmers and their families in order to achieve one or more objectives that govern the production process within a given set of constraints" (Capillon and Sebillotte, 1980). Capillon (op cit) proposes a method of describing farm management practices based on survey guidelines and farm management approaches. These include strategic choices and their determinants such as the choice of productions, labour force and equipment as well as environmental factors. Farm management decisions are analyzed within subsets (subsystems or production units), whose relationships are studied, and where advantages and constraints are related to the production equipment, the physical environment and the socio-economic context. This method is used to describe the diversity of farms on a regional level through farm typologies (Simon et al., 2000).

However, a deeper understanding of these farm management practices can be gained by a detailed analysis of agricultural techniques on crops, that is, "the basic activities and methods used from a production viewpoint" (Landais et al., 1990). Farming practices are considered to be one of the best ways to approach farm studies (Deffontaines and Raichon, 1981; Landais, 1987; Landais and Deffontaines, 1988; Osty et al., 1998). Our aim in analyzing the farmers’ practices is to define the constraints that guide their decisions and limit changes that can be made in the future (Jouve, 1986; Dounias et al., 2004). We focused on the practices used on farm cereal plots, basing our analysis on the crop management itinerary concept, that is, "a logical, ordered sequence of cultivation techniques applied to a specific crop type in order to achieve a certain level of production in a given environment" (Sebillotte, 1978). We assumed that the logic behind these crop management itineraries is to be found in individual farm objectives, resources and organization. Their impact on production depends on the variability of the environment (location and climate in the semi-arid region) and the type of farms. The crop management itineraries were determined according to the cultivation practices recorded on the farms (dates and modalities of operations) and surveys conducted to determine the reasons behind the choices made. We believe there is an inextricable link between a global analysis of farm management practices and a detailed analysis of grain cultivation practices.

Methodology

The Setif region (Figure 1) was selected because of its internal diversity based on three factors (a) the diversity of the environment, particularly according to the climatic degree of aridity. There are three semi-arid climate zones in the Setif region: upper, central and lower. The average annual rainfall decreases from the upper to the lower zones (200 to 150 mm), while the inter-annual precipitation variability increases. The variability between climatic zones is significant with a coefficient of variation in annual rainfall of 45%. (b) the diversity of farming systems, accessible with a general agricultural census across the three different climate zones. Various crops (cereals, potatoes, and market vegetables), livestock and combination between both are seen in these semi-arid regions (c) the diversity of the cereal production methods used, which was supposed but not informed when the work began. To take into account these factors of diversity, we organized the study by:

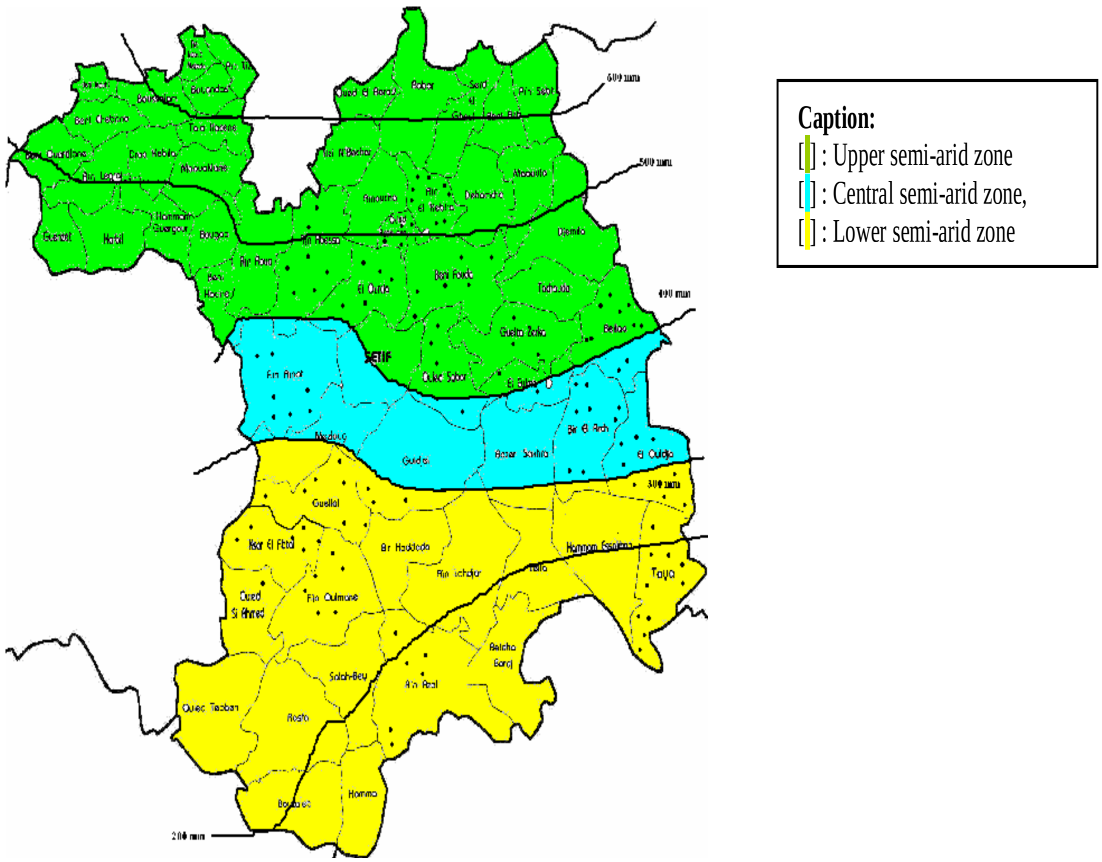

Figure 1. Presentation of the study region (according to Benniou et al., 2006)

Table 1. Choice of localities and breakdown of farms surveyed according to climatic zones.

Zones	Localities (number)	Farms (number)
USZ	8	46
CSZ	5	25
LSZ	10	49

USZ, Upper Semi arid Zone; CSZ, Central Semi arid Zone; LSZ, Lower Semi arid Zone.

1. Studying two contrasted climate periods, CY1 (2001/2002) with a total rainfall of 180 mm in same zone (the driest period in 22 years) and CY2 (2002/2003) with a total rainfall of 462 mm in the same zone. In addition, other climatic factors such as late frost and “sirocco” winds (hot winds from the south which are frequent in June), come into play, often coinciding with the critical physiological stages of grain development.
2. Making farms surveys in order to build a farm typology at regional level. We selected 120 farms in 21 grain-producing localities from the general census. The choice of farms is intended to reflect the diversity of production systems and use of resources (particularly irrigation) in the three climatic zones (Table 1).

The goal of this study was not to be representative in the statistical sense of diversity, but rather to represent the widest possible range of regional diversity in the choice of agricultural units, in accordance with Mitchell (1983).The farm typologies are based on two complementary methods: the first uses statistics obtained from a component analysis of the 120 farms, while the second consists in a functional typology according to the expert method proposed by Capillon (1993): farms are here classified according to similar management objectives, crop choice strategies, management practices and resources used (including land, tillage and water).
3. To analyze the cereal practices, we chose a sample of 16 reference farms among the upper 120, and inside these farms, all the cereal plots: 174 cereal plots were thus studied for the two climatic periods, the dates and modalities of cultural practices were recorded and the farmers were asked to explain the rationale behind their practices. The results were categorized into crop management itineraries. The sample of farms and plots could not be more numerous because the typology building proved to be very time-consuming,

RESULTS

Analysis of regional typology

The farm structure chosen by a farmer reflects a compromise between specialized and broad-based farming (Pluvinage, 1995). The environmental conditions and the different structures of each farm influence the organizational and production methods: they result in a diversity of production systems in the Setif High Plains characterized by the mixed crop-livestock model

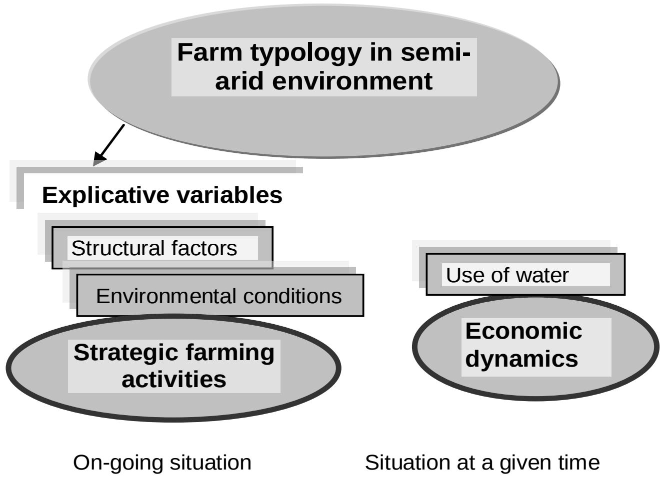

Figure 2. Typological analysis (first method) of farms.

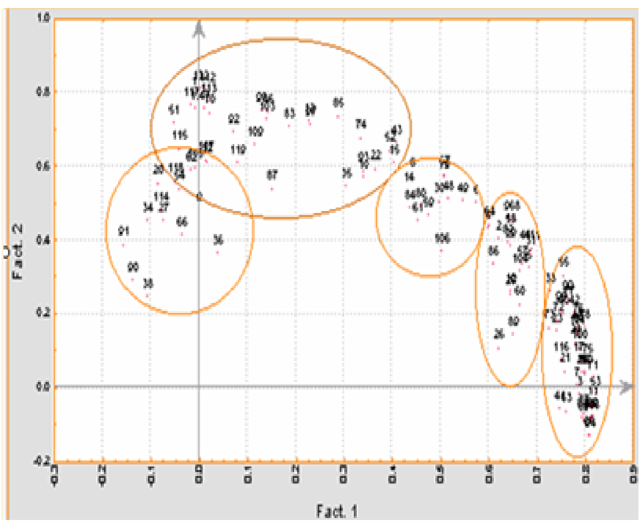

Figure 3. Analysis of main components. Legende: F1: Farms; F2: studied factors (structural's, climate, productions...).

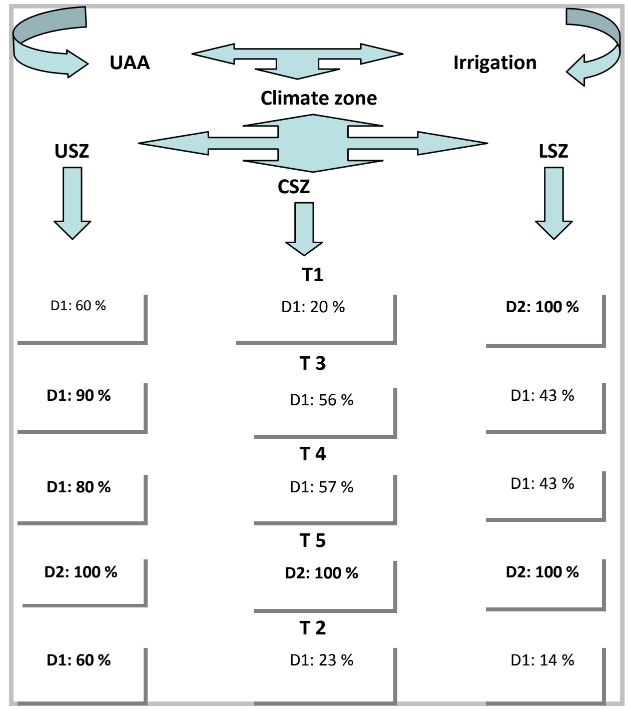

Figure 4. Type of farms according to strategic and economic factors. D1: dry, D2: dry, irrigated.

(Benniou et al., 2001). Our typology reflects and expands upon this overall finding.

A statistical analysis of the regional typology has brought to light two types of variables (Figure 2): (1) explicative variables, which reflect the strategic characteristics of the farms in the area and their economic orientation based on structural factors (utilized agricultural area, equipment, manual labor), the production combination and the environmental conditions; (2) dependent variables which reflect current economic trends that affect the economic dynamics of farms, such as the relationship between the diver-sification of farming systems and the use of irrigation.

The proposed typology (Figure 3), based on a component analysis, resulted in five farm management types (Benniou and Brinis, 2006). They are (1) type 1 (T1), small "mixed crop and livestock" farms; (2) type 2 (T2), small "mixed crop and mixed livestock" farms; (3) type 3 (T3), medium "grain crop and livestock" farms; (4) type 4 (T4), large "grain crop and livestock or grain crop, livestock and potato" farms; and (5) type 5 (T5), large "multiple crop and livestock" farms.

An example of farm functioning scheme, according to Capillon's expert method, is given in Annex 1. The distribution of the different farm types varies according to the climate zone (Figure 4), with a tendency towards a concentration of small farms in the lower semi-arid zone (LSZ). Similarly, the distribution of production systems within farm types varies widely. For example, all "type 1" farms in LSZ use irrigation to some extent. The same is true for all "type 5" farms. In USZ, however, the majority of farm types practice dry-land farming. As a result, crop management differs according to farm type and climate zone.

Crop management

Crop management itineraries are determined according to the farming activities observed on each farm (Figure 5). The farmer's practices are shown to be coherent in terms of both farm management and agricultural methods (Capillon and Leterme, 1986). The different farm management phases were analyzed and divided into crop management itinerary units (CMIU) according to which methods were employed and when. The

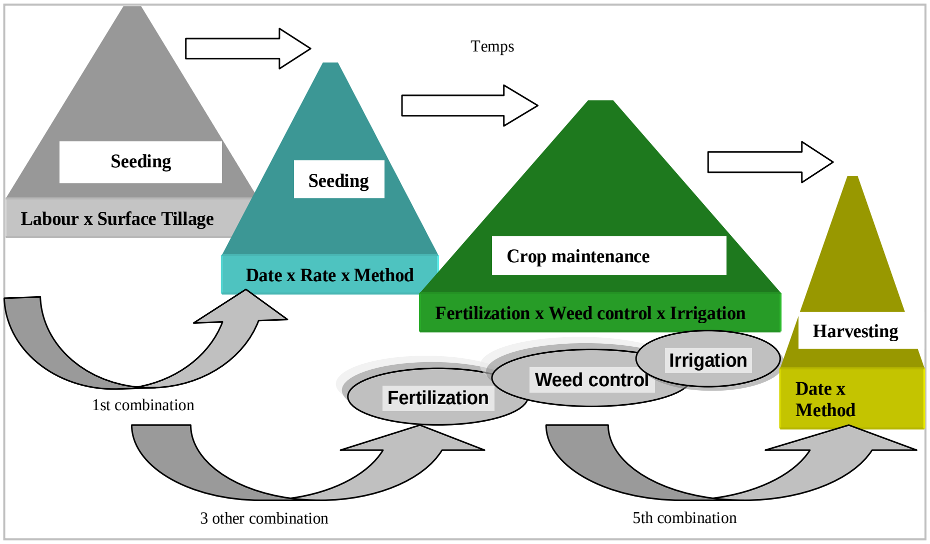

Figure 5. Potential combinations of different grain crop operations.

Table 2. Comparison of farms by type of tillage, climate zone, type of farm and year (U: in number of plots).

Zones/Year	Plowing crop management itinerary unit (cmiu)						
	CMIU 1.1	**CMIU 1.2**	**CMIU 1.3**	**CMIU 2.2**	**CMIU 2.3**	**CMIU 3.3**	**CMIU 4.0**
USZ	T3 : 4 T4 : 7 T5 : 09	T3 : 5 T5 : 4	- - -	T3 : 2 T4 : 8 T5 : 9	- - -	T2 : 6 T5 : 5 -	- - -
CSZ	T4 : 5 T5 : 3	T4 : 3 T5 : 10	- -	T3 : 10 T4 : 1 T5 : 5	T5 : 7		- -
LSZ	T4 : 02 T1 : 01	T5 : 2	- - - -	T1 : 2 T3 : 12 T4 : 4	T1 : 3 T3 : 7 T4 : 8 T5 : 15		T5 : 9
CY1: 94 Plots	Plot : 17	Plot : 15	-	Plot : 31	Plot : 24	Plot : 0	
CY2: 81 Plots	Plot : 14	Plot : 9	-	Plot : 22	Plot : 16	Plot : 20	Plot : 0

CY1, Crop year 2001/ 02; CY2, crop year 2002/ 03; USZ, upper semi-arid zone; CSZ, central semi-arid zone; LSZ, lower semi-arid zone.

management phases include tillage, seeding, crop maintenance and irrigation.

As a result, we selected tillage and seeding operations (time-frame and method) which vary from farmer to farmer, crop maintenance and especially fertilization, weed control and irrigation, which does not concern all farmers, and harvesting operations (not presented in this report).

Following is a detailed presentation of how we established the different combinations of tillage and seeding (typology I). It is followed by a brief synopsis of the main results of the combinations set out below including maintenance operations.

Typology I (tillage and seeding)

For tillage, seven basic CMIUs were established (Table 2) which combine deep plowing and surface tillage. Given the relative uniformity of the equipment used (disk plows), this typology is based mainly on when and how tillage is carried out. CMIUs in categories 1.i, 2.i, 3.i and 4 correspond to spring plowing, fall plowing, late plowing and no surface tillage respectively. CMIUs i.1, i.2, i.3 and i.0 correspond to early surface tillage, fall surface tillage, late surface tillage and plowing with no surface tillage respectively Table 2 shows that CMIU 2.2 (fall plowing, fall surface. tillage) is the unit most commonly found

Table 3. Comparison of seeding operations per CMIU during two years of monitoring per type of farm and climate zone (U: in number of plots).

Zones/ Year	CMIUs											
	S1H1	**S1H2**	**S1L1**	**S1L2**	**S2H1**	**S2H2**	**S2L1**	**S2L2**	**S3H1**	**S3H2**	**S3L1**	**S3L2**
USZ	T3: 4 T4: 5 T5: 11	T5:1	T5:6	T5: 1	T4:5	T3: 7 T4:5	0	T5: 3	0	T2: 6	0	T5: 5
CSZ	T4:2	0	0	0	T4: 4 T5: 8	T3: 2	T5:8 T4:1	T3: 2	T5-:4	T5:1	T4: 2 T5: 9	T3: 6 T5:1
LSZ	0	T1:1 T3: 5 T4: 1	0	T5:1	T5: 13	T3: 3 T5: 3	0	T3: 2 T3: 2	T4: 3 T5-:4	T1: 3 T3: 2 T4 :6	0	T1: 2 T3: 12
CY1	*11*	*5*	*5*	*0*	*25*	*17*	*8*	*7*	*2*	*5*	*0*	*8*
CY2	*11*	*3*	*1*	*2*	*5*	*3*	*1*	*2*	*9*	*13*	*11*	*18*
Total	*22*	*8*	*6*	*2*	*30*	*20*	*9*	*9*	*11*	*18*	*11*	*26*
Rate	*30*		*8*		*50*		*18*		*29*		*37*	
Period	CY1 : 21 + CY2 : 17 = 38				CY1 : 57 + CY2 : 11 = 68				CY1 : 15 + CY2 : 52 = 66			

CY1, Crop year 2001/02; CY2, crop year 2002/03 ; USZ, upper semi-arid zone; CSZ, central semi-arid zone; LSZ, lower semi-arid zone; S1H1, early sowing; high line; S1H2, early sowing; high on the fly; S1L1, early sowing; low line; S1L2, early sowing; low on the fly; S2H1, late sowing half; high line; S2H2, late sowing half; high en fly; S2L1, late sowing; low line; S2L2, late sowing half; low on the fly; S3H1, late sowing; high line; S3H2, late sowing; high en fly; S3L1, late sowing; low line; S3L2, late sowing; low on the fly

in the three climate zones, followed by CMIU 2.3 which is characterized by late tillage in the lower semi-arid zone. At the opposite end of the scale, CMIU 1.1 (early tillage) is prevalent in the upper semi-arid zone. Very late tillage (CMIU 3.3) is prevalent in high rainfall years in USZ and CSZ. Tillage tends to be carried out later on small farms than on large farms in any given zone.

The seeding method analysis (Table 3) indicates three seeding dates, two seeding rates and two seeding methods. We were able to combine these factors into 12 basic seeding units designated as follows: S1 (early seeding), S2 (mid-early seeding), S3 (late seeding), H (high rate), L (low rate), 1 (seed drilling) and 2 (broadcast seeding). Table 3 shows the breakdown of CMIUs by climate zone, farm size and crop year.

Early seeding units (S1) are not very common, being mainly found in USZ and, to a far lesser extent, in CSZ and LSZ. Unit S1H1, which corresponds best to crop management recommendations (early seeding, seed drilling, high seeding rate), is the most prevalent in USZ, particularly on large farms such as types T4, T5 and even T3. Unit S1H1 was used in USZ in CY1 and CY2. Unit S1H2 (early seeding, high rate and broadcast seeding) was only found in LSZ (farm types T1, T3 and T4) and only used for feed crops.

The "seasonal" seeding units S2 (October to November) are the most common across all the different zones and farm types. However, they are mainly found in CY1 (low rainfall). S2H1 is the most predominant unit and concerned large farms (T4 and T5) in all three climate zones, followed by the same CMIU, but with broadcast seeding (S2H2) and combined with various farm types (T4, T3, T5) and climate zones. In the case of units with a low seeding rate (S2L1 and S2L2), S2L1 was found mainly in T5 and S2L2 in T5 and T3. The S3 "late" seeding units were well represented overall, particularly in CY2. Unit S3H1 was not present in USZ and mainly concerns large farms (T4, T5) in CY2. S3H2 was practiced on farms of different sizes (T1, T3, T4 and T5, particularly in LSZ). In CY2, unit S3L1 was only used on large farms (T4 and T5) located in CSZ. Unit S3L2 concerns various types of farms, principally in CSZ.

Combining the different tillage and seeding units resulted in six crop management itinerary sets (CMIS). The first CMIS combines fall tillage (T2.2) with 9 seeding units and is by far the most common. However, the most frequent combination was T2.2 with S2H1, S2H2, S2L2 and S1L2. This can be explained by the fact that the prevailing agricultural production system in the region is extensive farming, particularly in CSZ and LSZ, for all farm types.

The second CMIS combines unit T1.1 (early tillage) with 6 seeding units. Group 1, which involves T1.1 and S1H1, focuses on wheat growing in USZ. The other CMIS include late tillage practices combined with late seeding dates, a low seeding rate and a predominately broadcast seeding method. These units were very frequently used in the second period (CY2), when the high autumn rainfall prevented early tillage practices, especially on small and medium farms. This shows once again that extensive crop management is the norm on these farms.

This combination of tillage, seeding and fertilization practices shows that only one crop management itinerary

Table 4. Types of crop management itineraries [tillage, seeding, fertilization, weed control and irrigation] for cases involving irrigation.

	Itinerary set I.1					
Level I tillage	T2.2					
Level II seeding	S1H2	S2H2	S2H1	S3H2	S2L1	S2L2
Level III fertilization	-	Fr.n	-	-	-	-
Level IV weed control	-	-	Ds.ch	-	-	-
Level V irrigation	S.I.	C.I.	S.I.	S.I.	S.I.	S.I.
	T5S (CY1-1) Oats T2I (CY2-1) Oats	T4 (CY1-1) Oats T2I (CY1-2) Oats T5I (CY1-1) Oats-Barley	T5C (CY1-2) Barley-Oats	T2I (CY2-1) Oats T2I (CY2-1) Barley	T5C (CY1-2) Durum wheat	T4I (CY2-1) Oats T2I (C71-2) Barley-Oats
Total plot :15	2	4	2	2	2	3
Fr. : 0.9%	13	27	13	13	13	20

	Itinerary set I.2					Itinerary set 1.3		Itinerary set 1.4		Itinerary set 1.5
Level I tillage	T23				L T	T1.2	L T	T3.3	L T	T4.0
Level II seeding	S3H1	S3H2	S3L1	S3L2	L II S	S2H1	L II S	S3H2	L II S	S3L2
Level III fertilization	-	Fr.n°	-	Fr.n°	L III F	-	L III F	Fr.n°	L III F	Fr.n°
Level IV weed control	-	-	-	-	L IV W C	-	L IV W C	-	L IV W C	-
Level V irrigation	S.I.	C.I.	S.I.	S.I.	L V I	S.I.		S.I.		S.I.
	T4I (CY2-2) Wheat-Oats	T4I (CY1-1) Durum wheat	T4C (CY2-2) Barley-Oats	T2I (CY2-2) Barley-Oats		T5I (CY1-1) Durum wheat		T5S (C72-1) Oats		T1I (CY-1) Barley
Total plot: Fr.	9 5%	3 33	2 22	2 22	Total plot: 01 Fr: 0.6%	1 100	Tot plot: 1 Fr: 0.6%	1 100	Tot plot: 1 Fr: 0.6%	1 100

(CMI) is “complete” in terms of cultivation practices and shows that intensive crop management is used for durum wheat production. T1.1 only concerns T3, T4 and T5 farms located in the upper semi-arid zone. The other CMIs are differentiated according to the soil tillage date, especially in USZ, the seeding dates and methods, and the use of fertilizer. In CSZ and LSZ fertilizer is rarely used and only concerns plots that require irrigation.

Combined typology: planting (tillage, seeding), fertilization, weed control and irrigation

This final typology represents the diversity of cereal crop management itineraries, from tillage to irrigation (Table 4). In this section, we have only presented the cases involving irrigation. These itinerary units are a defining characteristic of the lower semi-arid zone, because they concern all the different farms types (from T1 to T5). However, they were more commonly associated with small and medium farms and crop years with low rainfall (CY1). It can be seen that the use of water in crop management depends on the type of grain, with irrigation being mainly used for feed grains (oats, barley and durum wheat). Irrigation is seen to be associated with a wide variety of other techniques. Contrary to expectations and recommended crop management itineraries (at least in high potential zones), irrigation is not a method of intensive farming that is automatically linked with intensive fertilization, systematic weed control and early tillage. In fact, irrigation is more often used in conjunction with late tillage, broadcast seeding and low seeding rates, all of which are frequently used when growing coarse grains for feed. Farmers generally use supplemental irrigation immediately after crop emergence. Irrigation therefore serves as a safety net and is not necessarily a part of the intensive crop management itinerary. Nonetheless, irrigation is a very important technique for farmers in terms of crop yield and demonstrates their concern with ensuring a certain level especially for feed grains.

Table 5. Grain type yields per type of farm during CY1 and CY2.

Zone	Code; type d'expl.	Durum wheat				Common wheat				Barley			
		CY1		CY2		CY1		CY2		CY1		CY2	
		HP (N°.)	Yield	HP (N°)	Yield	HP (N°)	Yield	HP (N°.)	Yield	HP (N°)	Yield	HP (N°)	Yield
USZ	E1-T3	100 (4)	06	100 (6)	11	-	-	-	-	-	-	50 (2)	25
	E2- T3	100 (2)	19	-	-	-	-	100 (2)	25.7	-	-	-	-
	E3-T4	100 ((2)	12	100 (3)	18.4	-	-	100 (2)	27.7	100 (2)	6.7	100 (2)	16
	E4- T5	100 (4)	18	100 (5)	19.9	-	-	-	-	100 (1)	25	100 (1)	22
	E5- T5	45 (3)	21	100 (5)	5^{-}	-	-	-	-	-	-	-	-
Average USZ		75 (15)	16.3	100 (19)	17.5	-	-	100	17.9	75 (3)	16.3	80 (5)	20.6
CSZ	E6-T5	0	0	100 (1)	12	0	0	100 (3)	16.4	50 (1)	40*	100 (2)	26.2*
	E7-T5	40 (2)	10*	100 (13)	12.8	0	0	-	-	0	0	100 (1)	8.8
	E8-T3	-	-	100 (5)	5^{-}	50 (1)	0 .25	-	-	0	0	-	-
	E9-T4	-	-	-	-	100 (3)	3.8	100 (2)	14.3	100 (2)	6.7	100 (1)	13.3
Average CSZ		25 (2)	10*	100 (19)	11.5	40 (4)	3.5	80	15.2	33 (3)	23*	50 (4)	19.5
LSZ	E10-T4	50	7.5	100 (1)	20	-	-	100 (2)	13	50 (1)	20*	100 (2)	30*
	E11-T4	-	-	-	-	0	0	-	-	-	-	-	-
	E12-T3	0	0	100 (2)	09	-	-	-	-	0	0	100 (2)	17;7
	E13-T5	33	17*	100 (1)	17	-	-	100 (1)	14	40 (2)	5.8*	100 (1)	20
	E14-T3	-	-	100 (1)	11	-	-	-	-	0	0	100 (1)	15
	E15-T3	0	0	-	-	-	-	-	-	0	0	0	0^{-}
	E16-T1	-	-	-	-	0	0	100 (1)	13	-	-	-	-
Average LSZ		18	14.9*	97 (5)	15.9	0	0	100 (4)	15.2	21 (3)	8.5*	74 (6)	19.8

USZ, Upper semi-arid zone; CSZ, central semi-arid zone; LSZ, lower semi-arid zone; HP, Harvested plots (%); Yield (q/ha); (*), irrigation; (-), hail storm effect.

Crop management itinerary

As expected, the results in Table 5 show that in the case of rain-fed farming (without irrigation), cereal grain production is closely linked to the type of crop year and climate zone.

According to our records, in a low rainfall year (CY1), the main zone in which a non-zero yield was recorded was USZ. The farms in this zone had more expenses and higher profits than all the farms in CSZ and LSZ combined. In CSZ, the only farms that were able to harvest were type T5 and T4 with complete, rational crop management itineraries (T1.1 x S1H1, T1.2 x S2H1). In LSZ, there was zero yield in CY1, regardless of crop management practices whenever there was no irrigation, that is, the climate conditions were more important than the type of management. Nonetheless, there was significant cereal grain production on irrigated plots in CSZ and LSZ - mostly on farm types T4 and T5. These farms obtained small to medium profit margins due to the additional expense of irrigating part of the cereal grain crop. In CY2 (a heavy rainfall year) there was a slight difference in cereal grain production between climate zones. The yield was variable and predictable with respect to the climate zone. These different production strategies resulted in comparable profits because of their similar crop input applications. The variation in average yield between crop years (all cereal grain plots included) was significant (9.2 q/ ha) particularly when the climate zones are taken into account. In USZ, a loss of 33% was recorded between a heavy rainfall year and a low rainfall year, while the corresponding figures for CSZ and LSZ were 83 and 91% respectively.

In the heavy rainfall year (CY2), the durum wheat and barley yields were compared for several crop management itineraries (CMIs) in the three climate zones (Table 6). Depending on their internal strategy, farming systems can be either intensive or extensive. Intensive farming always aims at achieving a high yield, while in extensive farming systems; the goal is to achieve an average production level compared to that of the region as a whole. It is thus possible to produce an acceptable yield without using an intensive itinerary and thus obtain good results at lower cost.

The second comparison (Table 7), concerns crop management itineraries on farms in CSZ and LSZ during a low rainfall year (CY1). According to the logic of extensive farming, the aim here is to achieve an average grain yield relying completely on supplemental irrigation to eliminate the restricting factor of water. Farming system in CSZ and LSZ is based on fall cereal grains (wheat, barley and oats) in binary rotation with other

Table 6. Comparison of crop management itineraries in rainy year (CY2).

Farm itineraries	Crop management itineraries					cost/ ha		Yield obtained (q/ ha)
	Tillage	Seeding	Sertilization	Weed control	Irrigation	Average	Standard deviation	
Farm 1 CMI1	T3.3	S3H2	0	0	0	6700	275	11*
CMI2	T1.2	S2H2	0	0	0	7250	275	25**
Farm 2 CMI 3	T1.1	S1H1	Fr. p. n	Ds. ch.	0	13870	4065	18,4*
CMI 4	T2.2	S2H2	0	0	0	5740	4065	16**
Farm 3 CMI3	T1.1	S1H1	Fr. p. n	Ds. ch.	0	15360	4380	19.9*
CMI5	T2.2	S1L1	0	0	0	6600	4380	22**
Farm 4 CMI6	T1.2	S1L2	0	0	0	5000	0	5* (hail)
Farm 5 CMI7	T1.2	S3L1	0	0	0	6450	850	12*
CMI8	T2.3	S3L1	0	0	S.I.	8150	850	28**
Farm 6 CMI9	T3.3	S3L1	0	0	0	5250	280	7.3*
CMI9	T3.3	S3L1	0	0	0	5250	280	22.5*1
CMI10	T3.3	S3L1	0	0	0	4400	280	4.7**
Farm 7 CMI11	T2.2	S3H2	0	0	0	5840	4630	9*
CMI12	T2.2	S1H2	Manure	0	S.I.	15100	4630	17.7**
Farm 8 CMI13	T2.3	S3H2	0	0	S.I.	14800	100	17*
CMI13	T2.3	S3H2	0	0	S.I.	14600	100	20**
Farm 9 CMI14	T2.2	S3H2	0	0	S.I.	13.400	-	11*

(*), Durum wheat (variety 1); (*1), durum wheat (Variety 2); (**), barley, cost expressed in Algerian diners (€ 11 = 102.89 diners).

cereal grains or with feed or potatoes depending on the availability of water. In a low rainfall year, the additional expense of irrigation is a prerequisite for a good harvest combined with an extensive farming itinerary (itineraries 1 and 2). Without irrigation and irrespective of other expenses, there is no grain yield at all.

The use of supplemental irrigation clearly demonstrates the farmers' strategy of obtaining minimum production for the most widely used cereal grains (on-farm consumption, feed, seeding, sale, etc.). Only during years with heavy rainfall does this type of irrigation guarantee a good yield 22.5 q/ ha on average compared with 10 q/ ha in CY1.

DISCUSSION

Our work, based on on-farm research, compares the relationship between crop management itinerary and yield (Loyce and Wery, 2006; Doré and Meynard, 2006; Doré et al., 2007), and gives greater insight into production logic than would a simple survey of practices. Our research showed that in the semi-arid region, there is a direct relationship between the diversity of farm management methods and crop management itineraries, based on both region and climate. Our crop management itinerary typology demonstrates the presence of intensive itineraries in the upper semi-arid zones (early plowing, extensive surface tillage, complete fertilization regime, weed control) and "extensive" itineraries in the lower semi-arid zones which differ in several respects: late plowing, less surface tillage and less fertilizer application, chemical weed control only when necessary, and especially irrigation, which is often supplemental. Crossing regional farm-management typologies with crop management itineraries gives us a better understanding of farming strategies in the semi-arid region (Latiri-Souki and Aubry, 1988; Mohsen and Ben-Hamouda, 1999; Latiri et al., 1992). On farms growing grain, especially those in the lower semi-arid zone, irrigation is used primarily for secondary grains (oats, barley, durum wheat), which are grown as feed, chiefly for cattle, either on the farm itself or on neighboring farms (types T1 and T2). This demonstrates the importance of livestock in the long-term viability of these farms. We observed that irrigation is not used to grow grains except as a safety net. Supplemental irrigation is primarily used just after crop emergence, in association with late seeding, broadcast seeding and low-density seeding, all of which are characteristic of secondary grains. An intensive farming system, where more than one type of input is used per crop, is found mostly in the upper semi-arid zone and used exclusively for wheat. Grain yields were evaluated by comparing crop management itineraries for grains according to the climate zone and the type of farm. Even though yields varied according to the climatic year, they did not necessarily depend on the use of inputs, advocated by local agricultural authorities to maximize crop yields. Given the highly unpredictable and restrictive agro-climatic conditions (Hazell et al., 2001), farmers do not consider this to be their primary objective. They believe that profitability comes from having a diversified

Table 7. Comparison of dry and irrigated grain management in dry year (CY1).

Itinerary	Plot- surface area (ha)	Crop management itineraries				Cost/hectare		Yield obtained (q/ ha)
		Tillage	Seeding	Fertilization, weed control	Irrigation	Average in AD	Standard deviation	
CMI1 durum wheat	1- 2	T1.2	S2L1	0	S.I.	14.250	250	10*
CMI2 durum wheat	1- 2	T2.2	S2L1	0	S.I.	14.250	250	10*
CMI 3 barley	1-3	T1-2	S2H1	Fr. p.n / Ds. Ch.	S.I.	16.250	1950	40
CMI 3 oats	1-3	T1-2	S2H1	Fr. p.n / Ds. Ch.	S.I.	20.150	1950	20
CMI4 durum wheat	1- 14	T1.2 R	S2H1	0	S.I.	25.590	615	17
CMI5 barley	2-8,5	T1.2 R	S2H1	0	0	6750	100	5,8
CMI6 oats	1-4	T2.2 R	S2H1	0	C.I	26820	615	17,5

(*), Vitron variety; CMI, crop management itinerary; S.I., Supplemental irrigation; C.I., complementary irrigation; AD, Algerian diner.

farm and in particular from the interaction between crops and livestock production (Ben Salem and Smith, 2008). It is this interaction that provides greater insight into farm management strategies and crop yield expectations. While practices and performance indicators can be studied for individual farm plots, an understanding of management methods can only be achieved through a broader analysis of all the plots in the crop rotation system (Aubry, 1995; Aubry et al., 1998) and the farm taken as a whole. The use of irrigation is thus linked to farm revenues because of the increased productivity that results for certain crops (Benniou, 2008; Poussin et al., 2008). However, given the increasing shortage of water (Bouman, 2007), the possible consequences on a regional scale of the widespread use of irrigation, albeit supplemental, must be taken into consideration (Poussin et al., 2008).

After the farms had been analyzed individually, the focus was shifted to sets of farms which could be represented by the same model (type), either because of their structure, in a functional typology, or their practices in a crop management itinerary typology. Combining these two typologies would seem an original and dynamic way to understand the logic behind farmers' management practices (Cochet and Devienne, 2006). However, the time demands of this type of survey, both in terms of developing the typology and providing technico-economic monitoring of some of the farms, severely limited the number included in the study (120 and 16 farms respectively, out of a total of 12,000 farms in the region). Nevertheless, the sample distribution selected, based on agro-ecological climate zones and the use of production resources such as irrigation in LSZ, and enabled us to achieve our objective of exploring the diversity of the farms in the region rather than producing a proportionally representative survey.

Conclusion

Increasing cereal grain production is an essential issue in North Africa, given the importance of cereals in the local diet, in agriculture and in the economy as a whole (Jouve et al., 1995). Cereal grain yields in the semi-arid regions of Algeria remain low (Djenane, 1993; Lahmar, 1993). Although changes in the country's agricultural policy, such as greater financial incentive, protection of cereal grain farmers and better access to water, are necessary to raise production levels, we consider that production is also limited by the technical and economic management of the farms themselves. Agronomists must address these issues when classifying production systems and evaluating crop management systems according to agricultural practices. They must adopt a systemic approach which includes studies carried out at individual plot, crop rotation group and farm levels. Those working in the fields of development and scientific research alike must realize the importance of having a thorough understanding of the diversity of production and crop management systems on a regional level, according to the agro-ecological area. On-farm research needs to be carried out more often in order to gain better insight into the techniques and decision-making factors used by farmers, identify and rank the most important problems and develop regional typologies.

In these harsh regions, switching from an agronomic analysis of crop itineraries to on-farm research, in which the farm is taken as a whole, requires a shift in the focus of agronomists and animal scientists. However, by working in association with management researchers, these "new" agronomists and animal scientists will be able to develop new agricultural concepts and approaches that have both a cognitive and empowerment objective which should pose a major challenge for research in Algeria today.

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APPENDIX

Average dimension

UAA: 130 ha

Technical and economic result

Combination of growing grains and mixed farming

Characteristics of production facilities

Strategic constraints:
- climatic uncertainties,
- lack or absence of irrigation water,
- high cost of spare parts and equipment

Strategic advantages:
- Agricultural machinery: available of all necessary machinery makes it independent compared with other types of farming.
- Labor: 7,6 UTH
- Buildings: 700 m^2
- Availability of irrigation water (12 ha)
- Use of own stubble for grazing
- More integrated into market to provide satisfactory income

Environmental factors

Aridity

Strategy: Production system aimed at mixed farming and livestock to achieve aims according to production facilities:
- The aim sought is a pronounced tendency towards marketing of farm product, particularly grains.
- The most advanced in terms of intensification and diversification of economic activity.
- In rain-fed farming, the tendency of the production system is combined with mixed crop-livestock farming.
- Envisaged increase of sheep stock

Mixed crop-livestock system

- Speculation choice: diversification of grain species; mixed farming
- Management choice: - Grains are managed semi-extensively

Crop rotation
- Grains-fallow–feed–market gardening and/or potatoes
- Grain crop surface area: 90 ha

⟺

Herds:
Production units:
- *Milking cows:* 08
- *Fattening (bull-calves)* :05
- *Sheep (ewes):* 67
- *Fattening (lambs):* 47
- *Goats:* 02

Feeding requirements:
- Production
  * *straw:* 2.400 bales
↕
- Purchases
  * *Bran:* 420 q/ year
↕
- Sales
  * *straw* 1.900 bales/ year

- Sales: ←------→ - own consumption:
- *Primary grains:* 90%
- *Secondary grains* 60% (barley, oats)

⟺

- Sales: ←---→ - own consumption:
- *bull-calves and milk*: Yes - *milk*: Yes
- *lambs*: Yes - *wool*: Yes
- *bull-calves:* Yes
- *roasting fowls:* Yes

→ Choice in relation to production facilities

- Maximize the farm's income by mixed farming and integration into local market.

Appendix 1. A type T5 farm management approach (Large mixed crop/livestock farm).