Droughts: Will farmers change their decisions?

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Abstract

The main objective of the present work is to study how drought affects the farmers' decisions in a region periodically affected by droughts.

In order to achieve this objective, the limits of the area under study were established according to the geographic location. The farmers' responses were assessed at the level of the decision making process associated with changes in the agricultural production system and their consequences on the economic results.

The results obtained point out that the response of farmers to a situation of water scarcity depends on the various possibilities of their farms and their capacity to irrigate.

Résumé

L'objectif de ce travail est d'étudier quels sont les effets de la pénurie d'eau sur les décisions des producteurs dans une région qui est périodiquement affectée par des problèmes de sécheresse.

Pour atteindre cet objectif, les limites de la zone étudiée ont été établies sur la base de la localisation géographique. Les réponses des producteurs ont été évaluées sur le plan de la prise de décisions associées aux changements du système de production et à leurs conséquences sur le revenu agricole.

Les résultats montrent que la réponse des producteurs dans une situation de pénurie d'eau dépend de leur possibilité de diversifier les cultures et de leur capacité d'irrigation.

1. Introduction and Objectives

The main objective of the present work is to study how drought affects the farmers' decisions in a region periodically affected by droughts. More precisely, in different situations of vulnerability and consequences of drought, the farmers' responses were assessed at the level of the decision-making process associated with changes in the agricultural production system and its impacts on the economic results.

The term "drought" has been used to describe a set of poorly defined phenomena, corresponding to situations where "a significant water deficit is observed in a sufficiently extensive region" (Cunha, 1982).

While technology did not provide the possibility of controlling and successfully manipulating the water resources for storage and distribution to different user groups for various ends, these phenomena were accepted as unavoidable whims of nature or unfathomable divine fatalities. Originally perceived as occasional disasters, droughts can now also be viewed and defined as expected phenomena, for which one can be prepared (Vlachos, 1990), despite difficulties in determining their beginning and end.

Based on the application of a regional drought distribution model to the annual records of 55 hydrological years in Continental Portugal (from 1940/41 to 1994/95), Santos (1998) concludes that droughts affected more than half of the area of the territory during 17 years (31%), and affected the whole territory during 10 years (18%). The author also concludes that in the southern region of the country, the return periods are significantly shorter than in the northern region. In the 90's, droughts affected the whole country in 1991/92, 66% of the territory in 1992/93 and 84% in 1994/95. In the drought of 1994/95 the effect was particularly severe in the District of Beja.

For the present work, and for the region identified in the next section, the concept of drought was subdivided into two distinct situations: one corresponding to a consecutive number of years of water scarcity without affecting the use of resources stored in the reservoirs for irrigation; the second corresponds to longer periods of time during which the water stored is mainly canalised for urban consumption, affecting irrigated crops.

Thus, the purpose of this report is to simulate the farmer's decision making process under three distinct situations: a situation of water availability; a situation of a consecutive number of years of water scarcity which jeopardise the use of the resources stored in the reservoirs for agriculture, and finally, a situation where the stored water is mainly canalised for urban consumption, thus affecting the irrigated lands.

2. Methodology

2.1 Limits and characterisation of the studied Zone

The first step to establish the limits of the studied Zone

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was the identification of a territory periodically affected by droughts, with different situations concerning the vulnerability and consequences of the phenomena.

With these in mind, we have restricted the studied Zone to the municipalities of Aljustrel, Beja, Ferreira do Alentejo, Mértola and Serpa. The criteria on which the decision was based were essentially the following ones: predominance of dry-land agriculture, with an enormous vulnerability to drought (Mértola and Serpa); some occurrence of irrigated agriculture (Aljustrel and Ferreira do Alentejo); potential situations of conflict concerning the use of water between different sectors (urban and industrial use vs agricultural use – Beja, Aljustrel and Ferreira do Alentejo).

It is a Zone with a very low-density population rate, where the population is getting older and where the villages, rural in their majority, have significantly increased the number of houses with canalised water (these houses represented 90% of the total in 1991).

The population works in the following sectors (by decreasing order): services, agriculture, construction, manufacturing and, finally, fishing and mineral extraction.

In the studied Zone, very big farms significantly mark the agricultural structures – 18% of the farms occupy 74% of the Used Agricultural Area (UAA). The family farms correspond to 88% of total farms and the time farmers spend on their farms is divided as follows: 53,5% occupy less than half of their work time with their farms, 30,3% occupy more than half but not all of their work time and 26,2% are full time farmers.

In the universe of farms, irrigated farms are particularly interesting since they are responsible for the majority of water consumption. Nevertheless, the area possibly irrigated represents only 3,6% of the total UAA and the area effectively irrigated only represents 1,5% of the total UAA. On these farms, individual irrigated systems (mainly artesian wells) prevail, except in Aljustrel and Ferreira do Alentejo where the water comes from shallow lakes of collective irrigation systems. The irrigation occurs by gravity in most of the cases. Wherever water is raised, the principal method used is the electric engine. Finally, the principal irrigated activities are: corn, citrus, other fruits, forages and some industry-oriented activities such as tomato and sunflower.

2.2 Modelling of the representative farms

Within the restricted Zone under study (municipalities of Aljustrel, Beja, Ferreira do Alentejo, Mértola and Serpa) three sub-regions were identified whose land exploitation systems are representative of fairly distinct conditions and thus respond to the drought problem in different ways. The selection of these sub-regions was carried out according to their agricultural and pedological characteristics, having as "background" the social problems brought by concurrent water usage.

Regarding the agricultural and pedological characteristics, the information contained in various works on Alentejo was deemed sufficient (Sobral and Marado, 1987; Cary, 1985). The land exploration systems referred in these works were checked against data and opinions of specialists at the Alentejo Regional Agricultural Services and at the University of Évora and updated accordingly.

Three farms representative of each sub-region were selected, which, due to their different soil types and their different ease of access to water, led us to anticipate different farmers' reaction to drought. For these farms Linear Programming (LP) models were built, with which the effect of drought on the farmer's decision can be analysed. These models are well adapted to this type of assessment, as linear programming explicitly takes into consideration the circumstances under which the farmers produce (prices, resources). Through shadow prices, it can offer a rigorous and significant economic definition of "restrictions" or "limiting factors" (Knipscheer et al., 1983; McCarl & Nuthall, 1985). Through linear programming models it is possible to compare various technological options and consider the natural and economic factors that influence these options (Spharim and Seligman, 1983). On the other hand, linear programming makes it easy to determine the opportunity cost of the resources used in alternative systems and can be easily used to simulate probable scenarios (Knipscheer et al., 1983).

The objective of the various models developed is always to maximise the gross income of the farmer. Having these models as a base, and using a production simulator (EPIC), it was possible to determine production plans and economic results in distinct scenarios of water availability, that demonstrate the behaviour of farmers in two different scenarios: in a year of water availability (Reference Scenario) and in a year of drought but with available water for irrigation (Scenario 1). For the farm in sub-region 3, two different situations were considered under Scenario 1: in the first situation it was considered that the irrigated area would remain unchanged; in the second situation it was considered that the farmer could diversify his activity, increasing his irrigated area. On this farm we also studied a third scenario: a scenario of water scarcity, in which there is no water available for irrigation, as it is canalised for urban consumption (Scenario 2).

The sub-regions selected correspond to three well-known soil types, defined in a work done by Sobral and Marado (1987) as follows:

Region 1 - Is mainly made up of skeletal schist soils, that are rarely associated to schist Mediterranean soils, with shallow layers, and whose usage capacity class is predominantly E.

The poverty of this soil associated with the aridity of the climate provides for a poor and desolate landscape. The holm oak trees are rare (12%) and the cork trees are almost non-existent. Large areas are still dedicated to cereal production under very extensive systems, although producing very small yields. The uncultivated areas tend to increase. There is an effort to increase the forage area, which is still insignificant, as well as sown grassland, although increasing does not represent 10% of the region's area.

Region 2 - Mainly Brown-reddish Chalky Clays, highly decarbonated, originated from the basic metamorphic rocks and the Black Chalky clays, highly decarbonated, originated from diorites or gabros, both with calcareous infiltration. Associated with these (but in smaller proportion) are the Calcareous Clayey soils. The patches of Black Clays or Brown-reddish non-calcareous soils are small and rare. The usage capacity classes of these soils are A and B.

This is the area of Alentejo where crop production is most intensified. The systems are mostly cereals, mainly wheat, which is grown with very high technology.

Region 3 - Is mainly Hydromorphic Mediterranean Soils of non-Calcareous Materials. These are associated with Clayey Mediterranean soils of Calcareous Material and Calcareous Soils. The predominant soil usage capacity classes are C and B, although class D is not infrequent. Rarely there are patches of Classes A and E.

Dry-land crop production on cleared land is dominant, occupying approximately 46% of the area of this region. The second major type of land use is oak plantation, with a greater percentage of holm-oak than cork trees. In the Mediterranean Hydromorphic Soils of non-calcareous materials, extensive cropping systems are used, where the secondary cereal has been replaced in the rotation by forage. The main motive for this option is the low yields obtained with the cereals, especially in humid years. In the Red Mediterranean soils of Clayey Calcareous Materials, the production systems are generally semi-intensive, although the cereal yields are much higher than in the previous soils and systems.

The importance of irrigation in this region should be emphasised, as it is included in the irrigation district of Odivelas. The simplified matrix of the model used is presented in Table 1.

Table 1. *Simplified matrix of the model*

Activities	Agricultural Activities			Animal Activities (AA)	Resource Buying Activities (AC)		
Restrictions	Dry-land (AS)	Irrigated-land (AR)	Set-Aside (SA)			Rel	Right Hand Side
Objective function	$MBS_{(c,z,p,a)}$	$MBR_{(c,z,p,a)}$	$MSA_{(c,z,p,a)}$	$MBA_{(c,z,p,a)}$	-CR	=	0
Land							
Dry land	1					≤	Ha_s
Irrigated land		1				≤	Ha_r
Set-aside			1				
Set-aside	0,0526	0,0526	-1			=	0
Work							
Tractor driver							
Period 1	$NMTS_{c,z,p,a,pv1}$	$NMTR_{c,z,p,a,pv1}$		$NMTA_{aa,pv1}$	-EMT	≤	DMT_{pv1}
Sub-period 1.1	$NMTS_{c,z,p,a,pv11}$	$NMTR_{c,z,p,a,pv11}$		$NMTA_{aa,pv11}$	-EMT	≤	DMT_{pv11}
:	$NMTS_{c,z,p,a,pv1..}$	$NMTR_{c,z,p,a,pv1..}$		$NMTA_{aa,pv1..}$	-EMT	≤	$DMT_{pv1..}$
Period 2	$NMTS_{c,z,p,a,pv2}$	$NMTR_{c,z,p,a,pv2}$		$NMTA_{aa,pv2}$	-EMT	≤	DMT_{pv2}
Sub-period 2.1	$NMTS_{c,z,p,a,pv21}$	$NMTR_{c,z,p,a,pv21}$		$NMTA_{aa,pv21}$	-EMT	≤	DMT_{pv21}
:	$NMTS_{c,z,p,a,pv..}$	$NMTR_{c,z,p,a,pv..}$		$NMTA_{aa,pv..}$	-EMT	≤	$DMT_{pv..}$
Shepherd							
Period 1				$NMA_{aa,pma1}$	-EMA	≤	DMA_{pma1}
Sub-period 1.1				$NMA_{aa,pma11}$	-EMA	≤	DMA_{pma11}
:				$NMA_{aa,pma1..}$	-EMA	≤	$DMA_{pma1..}$
Period 2				$NMA_{aa,pma2}$	-EMA	≤	DMA_{pma2}
Sub-period 2.1				$NMA_{aa,pma21}$	-EMA	≤	DMA_{pma21}
:				$NMA_{aa,pma..}$	-EMA	≤	$DMA_{pma..}$
Machinery							
Tractor							
Period 1	$NTS_{c,z,p,a,t,pv1}$	$NTR_{c,z,p,a,t,pv1}$		$NTA_{aa,t,pv1}$	-ET	≤	$DT_{t,pv1}$
:	$NTS_{c,z,p,a,t,pv..}$	$NTR_{c,z,p,a,t,pv..}$		$NTA_{aa,t,pv..}$	-ET	≤	$DT_{t,pv..}$
Recollection machine							
Period 1	$NCS_{c,z,p,a,c,pv1}$	$NCR_{c,z,p,a,c,pv1}$			-EC	≤	$DTC_{1,pv1}$
:	$NCS_{c,z,p,a,c,pv..}$	$NCR_{c,z,p,a,c,pv..}$			-EC	≤	$DTC_{1,pv..}$
Minimum nutrient needs							
ME							
Period 1	$MES_{c,z,pa,pro,pa1}$	$MER_{c,z,pa,pro,pa1}$		$+NME_{aa,ca,pa1}$	$-EMC_{proe}$	≤	0
:	$MES_{c,z,pa,pro,pa..}$	$MER_{c,z,pa,pro,pa..}$		$+NME_{aa,ca,pa..}$	$-EMC_{proe}$	≤	0
CP							
Period 1	$CPS_{c,z,pa,pro,pa1}$	$CPR_{c,z,pa,pro,pa1}$		$+NPB_{aa,ca,pa1}$	$-CPC_{proe}$	≤	0
:	$CPS_{c,z,pa,pro,pa..}$	$CPR_{c,z,pa,pro,pa..}$		$+NPB_{aa,ca,pa..}$	$-CPC_{proe}$	≤	0
Maximum ingestion capacity							
Period 1	$-DMS_{c,z,pa,pro,pa1}$	$-DMR_{c,z,pa,pro,pa1}$		$IC_{aa,ca,pa1}$	$-DMC_{proe}$	≥	0
:	$-DMS_{c,z,pa,pro,pa.}$	$-DMR_{c,z,pa,pro,pa..}$		$IC_{aa,ca,pa..}$	$-DMC_{proe}$	≥	0
Water		A_{cz}				≤	DA

Fig. 1. *Scenario of water availability*		
Region 1 farm Gross Income: 114 664		
	Crop Production	Rotations: Fallow with tillage - Durum wheat – Wheat Fallow – Fallow – Fallow – Fallow – Fallow 202.5 ha Pasture of underground clover 305.0 ha Natural pasture 335.0 ha
	Livestock Production	2 082 breeding ewes 65 breeding cows
Region 2 farm Gross Income: 126 111		
Crop Production	Clay Blocks	Rotations: Sunflower – Durum wheat – Barley 200.5 ha
	Schist Blocks	Rotations: Triticale - Oat– Fallow – Fallow 165.6 ha
	Livestock Production	614 breeding ewes
Region 3 farm Gross Income: 231 873		
Crop Production	Dry-land	Rotations: Sunflower - Durum wheat – Barley 60.0 ha Pasture 326.0 ha
	Irrigated	Rotations: Corn –Durum wheat – Wheat Corn – Forage corn – Sunflower 142 ha
	Livestock Production	150 breeding cows
Source: Results from the Model		

3. Results

3.1 Economic results and production plans of the representative farms in a scenario of water availability

The economic results and the production plan of the farms considered as typical of the selected regions were obtained using the linear programming model developed by the project team. In the reference scenario, the results are as follows in Fig 1.

3.2. Economic results and production plans of the representative farms in a scenario of water scarcity

Scenario 1 -Years of drought in which the productivity of dry-land crops is low, but there is water available for irrigation.

For this scenario, the economic result and the production plan of the farms studied in the above mentioned situations are as follows in Fig 2.

Scenario 2 - Drought years in which there is no water available for irrigation.

For this scenario the results are as follows in Fig. 3.

4. Conclusions

In the three farms selected as representative of the areas under study the farmers respond to droughts making a few changes in their production plans.

In region 1, the possibility of diversifying the cropping pattern of the farm is very small, and thus, the response to drought is basically limited to changing the area used by the first part of the rotation, in order to be able to continue feeding the cattle and the sheep herds, and even so, the latter has to be very small. With the impossibility of maintaining the herds, which contribute decisively to the formation of gross income, it is unavoidable that the results should fall drastically. This demonstrates the lack of alternatives for the farmer, who, in the reference year, has a gross margin very similar to that obtained in region 2, which is traditionally considered a rich area.

In region 2, the farmer responds to drought by diversifying his cropping pattern. On one hand, he uses crops that respond better under conditions of drought, and decreases his intermediate inputs; on the other, he diversifies the sources of his income and essentially directs his farm towards livestock production. Nevertheless, his income also decreases substantially.

In region 3, the farmer does not respond to drought if he can maintain his irrigated area but cannot increase it, thus suffering only a small fall in income. If it is possible to increase the irrigated area, he will use all of the area under irrigated rotations and will diversify, using rotations that allow him to increase his incomes and maintain the cattle herd. Finally, when the drought situation is so severe that the reservoir water is canalised to urban consumption and the farmer is prevented from irrigating, he responds by using all the area available for rotations with a rotation of Sunflower – Durum wheat – Barley, whose gross income is, even under these conditions, positive, and will grow only some 4 ha of oats for hay, which will be used to complement the feed of the existing cattle. Despite these changes, his income will obviously be reduced substantially.

Table 2. *Summary of the principal conclusions of the study*

Farms		Drought years	Effects on agricultural returns	Effects on production diversification	Effects on intermediate inputs
"Rich" Farms	Irrigated agriculture	With irrigation	-	+	+
		Without irrigation	--	++	-
	Dry-land agriculture		-	+	-
"Poor" Farms in dry- land agriculture			--	=	-

In summary (Table 2), it is possible to conclude that the farmers' responses to drought situations depend essentially on their ability to diversify their production. When this is possible, the farmers can devise solutions that allow them to maintain their income. When it is not possible, the response to drought is essentially to maintain a very extensive production system that will allow them to recover in more favourable years. Finally, we can observe that the possibility of producing irrigated crops has a stabilising effect on the income obtained under conditions of drought.

References

Abreu, M. C. (1993) Valor Alimentar de Três Pastagens Anuais para Ovinos. Dissertação apresentada à Universidade de Évora para Obtenção do Grau de Doutor em Ciências Agrárias, especialidade de Nutrição e Alimentação, Universidade de Évora, Évora.

Cabelguenne, M. e DebaeKe Ph. (1993) Analyse des Impacts Socio-économiques des Différentes Politiques des Certaines Régions Européennes: Compétitivité et Protection de l'Environnement. Comission des Communautés Europeénnes, DG VI - Agriculture.

Cary, F. (1985) Enquadramento e perfis do Investimento Agrícola no Continente Português. Banco de Fomento Nacional, Estudos 22, Vol. 1 e 2, Vila da Maia.

Cunha, L. V. (1982) As secas - caracterização, impactes e mitigação. Secretaria de Estado do Urbanismo, Comissão Nacional do Ambiente, Lisboa

Knipscheer, H. C., Menz, K. M. & Verinumbe, I. (1983) The Evaluation of Preliminary Farming Systems Technologies: Zero-Tillage Systems in West Africa. Agricultural Systems, 11, 95-103.

Marques, C. (1988) Portuguese Entrance into the European Community: Implications for Dryland Agriculture in the Alentejo Region. PhD Thesis, Purdue University, Purdue.

Marques, C. (1992) Implementações Empíricas Base de Modelos de Programação Linear de Empresas Agrícolas Representativas do Alentejo. Anais da Universidade de Évora (2).

McCarl, B. A. & Nuthall, P. (1985) Linear Programming for Repeated Use in the Analysis of Agricultural Systems. Agricultural Systems, 8, 17-39.

Santos, A. (1998) Caracterização e Monitorização de Secas. Instituto da Água, Direcção de Serviços de Recursos Hídricos, Lisboa.

Serrão, A. (1988) Farm-level response to Agricultural Development Strategies in the Evora Dryland Region of Portugal. PhD Thesis, Purdue University, Purdue

Sobral e Marado, (1987) Programa de Drenagem e Conservação do Solo no Alentejo. Modelos de Exploração das terras do Alentejo (META). Zonas Agro-Ecológicas no Alentejo. Ministério da Agricultura, Pescas e Alimentação. Direcção Geral de Hidráulica e Engenharia Agrícola, Évora.

Spharin, I. & Seligman, N. G. (1983) Identification and Selection of Technology for a Specific Agricultural Region: A Case Study of Sheep Husbandry and Dryland Farming in the North Negev of Israel. Agricultural Systems, 10, 99-125.

Vlachos, E. (1990) Drought Perception and Societal Consequences. Invited paper, Royal Academy of Exact Sciences, Madrid.

Fig. 2. *Scenario 1*

Region 1 farm Gross Income: 43 490		
Crop Production		Rotations: Oats for hay and oats for grain 50 ha Pasture 300 ha
Livestock Production		543 breeding ewes 65 breeding cows
Region 2 farm Gross Income: 70 844		
Crop Production	Clay Blocks	Rotations: Sunflower - Durum wheat – Barley Wheat Durum wheat – Chick peas 200.5 ha
	Schist Blocks	Pasture 138.0 ha
Livestock Production		1072 breeding ewes
Region 3 farm *Situation 1:* Gross Income: 223 491		
Crop Production	Dry-land	Rotations: Sunflower - Durum wheat – Barley 60.0 ha Pasture 326.0 ha
	Irrigated	Rotations: Corn –Durum wheat – Wheat Corn – Forage corn – Sunflower 142 ha
Livestock Production		150 breeding cows
Region 3 farm *Situation 2:* Gross Income: 272 019		
Crop Production	Dry-land	Pasture 326.0 ha
	Irrigated	Rotations: Sunflower – Corn - Wheat Corn – Durum wheat – Wheat 202.0 ha
Livestock Production		150 breeding cows

Source: Results from the Model

Fig 3. *Scenario 2*

Gross Income: 115 911		
Crop Production	Dry-land	Rotations: Sunflower - Durum wheat – Barley Oats for hay 202.0 ha Pasture 326.0 ha
	Livestock Production	150 breeding cows

Source: Results from the Model