# MANAGING RURAL AREAS: METHODS FOR THE EX-ANTE EVALUATION AND SELECTION OF LAND CONSOLIDATION ACTIONS (LC'S) TO IMPLEMENT.

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**ABSTRACT:** *Rural areas are confronted with problems of economic development and of the management of natural resources and national heritage against a background of increasing competition between regions and of rapid socio-economic and institutional change. Trough history, a continuous effort has been made to adjust the structure of the countryside to human needs. During the last 25 years, land consolidation has been an important instrument of rural planning in Portugal and, essentially, a tool for improving the effectiveness of land cultivation and for supporting rural development. During these years, the objectives have grown from a pure agrarian instrument, to increase agricultural production, towards an integrated rural planning instrument, taking into account all functions accountable to rural areas. Presently, in Portugal, we are under a situation where the demand for Integrated Land Consolidation actions (LC's) clearly exceeds the available public resources affected to do it. So, a decision-making support system approach, to aid the preordination and selection of the submitted projects will proposals, is viewed as a critical issue. The main objective of this paper is to respond to that necessity and sustain the advantage of possessing a simplified method for the selection of the LC's to implement. With those purposes we developed a multiple regression model that explains a significant proportion of the variability of the economic results as a function of some variables capable to capture and describe de main characteristics of the LC's. Such a model may be a simple, easy and effective tool to evaluate a priori, in the initial stage of the previous study and based on the ex-ante economic evaluation, the urgency and the potential of a particular area to be beneficiated with a land consolidation action. The paper is structured in four sections: in the first, the introduction, we present a general discussion about the necessity, the purposes and the extent of doing land consolidation actions; in the second, we present and detail the data from twenty previous studies of LC actions carried out in Portugal in the last three decades; in the third, we present and estimate the linear regression, suggesting the basic factors to include in a decision support system for the selection of the Land Consolidation actions to implement; lastly, in the fourth section, we report the conclusions of this study.*

**KEYWORDS**: land consolidation, rural planning and development, ex-ante evaluation

## INTRODUCTION

Nowadays rural areas are confronted with problems of economic development and of the management of natural resources and national heritage against a background of increasing competition between regions and of rapid socio-economic and institutional change.

The signs of this crisis are today vary visible in Portugal, particularly on less developed or less favourable rural territories (deep interior and mountain territories), assuming the form, for instance, of continuous depopulation (Ludovico, 2018), farming abandonment and more frequent and tragic fires On the origin of these tendencies are, beside factors of littoral and urban attraction, repulsive rural factors, like the increase of the young people levels of education, qualification and ambition, and the lack of competitiveness of the agriculture, witch remains the main, when not the solely, economic activity of those regions. The rate of fixation of young people on a particular territory is one of the best indicators of its socio-economic health and development expectations. From this angle, the question of the recent past and the future of the less developed or less favourable rural territories, acquires a progressive and pronounced black concern (INE, Census of population in 1991, 2001 and 2011).

Today, on larger part of Portuguese rural territories the tendency is to move towards to few people and to much land. This surplus of agricultural land, because of the increasing environmental restrictions that are being imposed on alternative uses, tends to depreciate land very quickly. Therefore, the surplus of agricultural land have to be redistributed or spatiality reallocated between the remaining farmers, otherwise it will be abandoned, with clear and negative consequences to the confining fields, and with a great loss of their usage, patrimonial and, even, ecological value. A successful land planning policy, concerned on the definition of long term land reserves for agricultural, ecological, urban, industrial or other purposes, should be based on three pillars: administrative approach (laws and related persuasive and coercive measures); economic incentives that translate and internalize the "social value" of a particular use of land; and, concrete policy instruments.

The administrative approach, although is very developed, lonely and for itself does not solve the problem. Particularly in Portugal, every day we may see examples of how the laws and regulations are ignored, contoured or over passed. Therefore, what really misses are incentives that clearly traduces the "social value" of a particular land use and the instruments of realization that impose the norm and give the example, like Land Consolidation (LC).

Through history, a continuous effort has been made to adjust the structure of the countryside to human needs. During the last decades, LC has been an important instrument of rural planning in Europe (Grossman and Brussaard, 1992; Meuser, 1992; European Commission, 1999; Crecente and Álvarez, 1999, 2000; BSLF, 2000; Ridell and Rembold, 2002; Hartvigsen, 2013, 2014a, 2014b). LC is also used in many non-European countries, including Japan, India, China, Indonesia and Turkey (Zhou, 1996; Oldenburg, 1990). The objectives of LC have grown from a pure agrarian

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instrument to increase agricultural production and efficiency (Madden, 1967, 1988; Simons, 1986, 1987; King & Burton, 1989), towards an integrated rural planning instrument taking into account all functions accountable to the development of the rural areas (Fresco, 1994).

As a pure agrarian instrument LC is a process whereby an area of land that is initially divided in many small plots is redefined and redistributed. Initially, the plots that constitute the holding of a typical landowner are scattered throughout the area. By applying land consolidation, the typical landowner has a holding with fewer, larger and less widely scattered plots, but the same soil-quality-weighted total area as before. From the point of view of land ownership, LC should also lead to "full ownership", i.e., ensuring that modern agricultural machinery will have access to each plot belonging to each landowner. Therefore, the LC process, primarily, intends to favours the rational land use and the mechanization of agriculture, solving situations where the basic features are (Brabec and Smith, 2002): unsuitable plot sizes (small plots unsuitable for modern mechanized agriculture); unsuitable plot shapes ("strap plots", acute angles, etc.); inaccessible plots (removal of original field roads); plots belonging to the same landowner that are scattered over numerous non-continuous plots.

As an integrated rural planning and land management instrument LC is regarded very favourably by many planners and planning theorists who hold that it promotes land markets and rural development - and thereby helps combat rural depopulation - by improving farm productivity as the result of easier mechanization and reduced work and transport costs (Thomas, 2006). LC is also view as a very useful instrument for erosion control in rural landscapes (Mihara, 1996), for dealing with nature conservation and environmental issues (Uhling, 1989), for rationalizing urban development (González et al., 2004) and other social and economic issues in managing the development of rural areas (Quadflieg, 1997). In resume, land consolidation is currently seen as essential for ensuring the economic viability of rural areas, facilitating environmental management or rationalizing urban growth (Sonnemberg, 1996; van den Brink, 1999; van Lier, 2000; Crecente et al. 2002; Carsjens and van der Knaap, 2002). For Zimmermann (1995), "Land consolidation has in Germany and in a number of other countries long been recognised as a most efficient tool to support the implementation of a modern national land policy. It has proven to be effective in specific situations in creating better conditions of a better life in the rural and urban environment and improving the sustainable use of the resources and the public facilities (especially roads)."

However, LC has also opponents, witch hold that it promotes over-intensification of agricultural practices and consequent environmental damage, including the lost of landscape diversity (Grossman and Brussaard, 1992; Güttinger, 1998). Moreover, they consider that in many cases the complexity of the consolidation process leads to public resources being wasted on consolidation schemes that become bogged-down and are never completed (Monke, 1992). In response to these criticisms, economic and environment-conscious countries now require prior evaluation of economic and environmental impacts, conservation or rehabilitation of landscape, the inclusion of economical and environmental specialists in planning teams, and compliance



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with environment protection norms (Crecente *et al.*, 2002; van Lier, 2000). In many countries, the declared objectives and methods of land consolidation have broadened to consider the increasing importance of non-agricultural uses of rural land and to facilitate the harmonious growth of towns and cities, as is implicit in the above quotation from Zimmermann (van Lier, 2000; Magel, 2000; Jacobs, 2000).

Research attempting objective ex-ante evaluation of LC has largely centred on specific cases or on specific aspects such as social or economic effects (Janssen and Rietveld, 1985; van den Noort, 1987; van Huylenbroeck and Martens, 1992; Coelho *et al.*, 1996; van Huylenbroeck *et al.*, 1996; Goodale and Sky, 1998; Lusho and Papa, 1998; van den Brink, 1999; van Dijk, 2000).

The objectives and methodologies of LC are influenced by the specific conditions in different countries and regions, by their historical and more recent political and social development (Sklenicka, 2002, Sklenicka and Lhota 2002), and also by the natural conditions (Eichenauer and Joeris, 1994; Bonfanti *et al.*, 1997; Mander and Jongman, 1998; Borec, 2000; Crecente *et al.*, 2002; Gorton and White, 2003).

In some cases, land consolidation should be more oriented to improve the aspects related to the efficiency of agricultural production. In others, it should be oriented to over pass conflicts or to turn out compatible distinguish objectives of social, economic or environmental nature. In both cases, the European countries that longer and largely had conduced LC actions (Germany, Holland, France and Spain) already did understood something: LC, mainly the comprehensive, complex and integrated one (because it is though and conduced in a holistic and participative way), is the most powerful and participative instrument of intervention on the rural space. Today, every, complex or simple, LC action is submitted to a public, direct and transparent, scrutiny, first, and more important, by the local population and farmers and, second, by various and numerous public entities with voice in the matter (Municipalities, Agricultural Ministry, Environmental Ministry, Environmental Associations, etc.).

Pure, or simple, Consolidation, that merely corresponds to the change of some plots between, necessarily few, farms or to corrections of the fields boundaries, is a relative inexpensive instrument, and should be indispensable always when the construction of a public infrastructure (for example, a road or a railroad) implies the amputation or the division of one or more parcels of one or few farms. The spatial cost associated to do that infrastructure should be fairly distributed over a significant area of parcels and farms and not only exclusively be imposed and absorbed by the few amputated or divided farms.

When we face the possibility of implementing an irrigation/drainage project there are an increased potential interest on the simultaneous realization of a LC connected action. The Portuguese experience on such situations clearly prove it (Coelho, 1996a, 1996b), advising that, at least, the ex-ante evaluation of an integrated LC action should be done.



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Our experience on areas where agricultural production and environmental conservation or protection are both and simultaneously pursued, like the cases of the "Mondego" and the "Baixo Vouga Lagunar" projects, goes in the sense of considering the integrated LC as the most adequate and powerful tool to use. A flexible and comprehensive instrument such as the integrated LC can only manage the conflict between farmers that want to conserve the land by doing what they ever had done, and those who want to preserve, studying, visiting or commercializing the nature. Normally, the degradation of these particular kind of environments is not related to the agriculture and the traditional farming practices that are going on, those, on contrary, both creates and sustains the ecosystem, but more frequently on their significant reduction or even absence. The reduction of farming, leading to the abandonment of the fields, is caused by the loss of competitiveness of the farms and farmers, due to inadequate farm structure and old farming practices. In order to preserve those ecosystems we may choose two alternative ways of intervention: the farmers participatory and farms restructure way; or, the administrative and coercive way. It is possible that the short term impacts are in favour of the coercive way, but we should also consider that in the long term the coercive way is always much more difficult to socially, economically and environmentally sustain.

Table 1 presents some elements of differentiation between the multiple forms of LC and it's adequacy to different situations.

**Table 1.** Elements of differentiation between the multiple forms of Land Consolidation.

| Forms of Land Consolidation | nº of landowners | nº of farmers | Total nº of plots | Works and Infrastructures | Volume of land exchanges |
|---|---|---|---|---|---|
| *Integral or Integrated* | Big | Big | Big | Many and expensive | High |
| *Partial or Simple* | Small | Small | Small | Null or few | Low |
| *Farm consolidation* | Variable | Variable | Variable | Variable | High |
| *Farm redimension* | Small | One | Small | Null or few | - |
| *Exchange of fields or trees* | Small | Small | Small | Null or few | Low |

Presently, in Portugal, we are under a situation where the demand for Integrated Land Consolidation actions clearly exceeds the available public resources, either human or economic, affected to do it. Therefore, a decision-making support tool, to aid the preordination and selection of the submitted projects will proposals, is viewed as a critical issue. Additionally, the usual method of performing de ex-ante evaluation of the projects in the previous study fase in Portugal (Coelho, 1992), although having proved to be consistent and accurate, is a heavy and long time consuming one. Given so, the pertinent question that should be asked is how to simplify the process without omitting any important component?



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In this paper, we explore the hypothesis of using a multiple linear regression model to capture and explain a significant part of the variability of the economic results driven by LC actions, and we present a case study, based on twenty previous studies of LC actions carried out in Portugal in the last three decades. In Section2, we present and detail the data from the twenty previous studies of LC actions carried out in Portugal in the last three decades; in Section 3, we present and estimate the linear regression model; and, lastly, in Section 4, we report the conclusions of this study.

## THE DATA

The data used in this study comes from the technical-economic evaluation reports of twenty previous studies of LC actions persuade in Portugal, all coordinated by Coelho. All the variables used in those studies to translate de structural and economic characteristics of the farms samples of each LC project, are of common use since Coelho (1992). For the reader less familiarized with these themes we recommend the consultation of Coelho (1992, 1996a, 1996b), Coelho and Portela (1994) and Coelho *et al.* (1996, 2001).

Next, we present three tables with the average indicators referring to the sample characteristics of the 20 cases studied. The first table (Table 2) shows the initial or reference situation and concerns the 11 characteristics (variables) observed on the holdings of the samples. The second table (Table 3) portrays the hypothetical final or post-project situation, and refers to the investment volumes and simulated characteristics (variables) of those holdings and samples. In addition, the third table (Table 4), resulting from the comparison of the values recorded in the previous two tables, presents the percentage of changes achieved in the various variables with the hypothetical completion of the project.

In addition, the original data come from surveys on representative samples of the universe of perimeter farms. The representativeness of the samples has always been ensured at two levels: relative weight (always equal to or greater than 10% of the number and total area of holdings) and specific weight (distribution of holdings by area and number of plots and, in some cases, also the age of farmers).

Finally, it should be noted that the results of the average farm revenue per hectare (REV) variable were estimated for the situations before and after the parceling, based on the model described in Coelho (1992), Huylenbroeck *et al*. (1996) and Coelho *et al*. (2001).



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**Table 2.** Characterization of the initial situation of the twenty LC projects (situation before LC - reference scenario).

| LC project (nº) | AFS (ha) | ANP | APS (ha) | APD (km) | AGE (years) | EDUC (%) | FED (%) | PS Coef. | RQ Coef. | UNC (%) | REV (cts/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Valença (1) | 1,89 | 9,50 | 0,15 | 1,20 | 63 | 4 | 93 | 1,76 | 1,52 | 11,00 | 379 |
| Samodães (2) | 3,34 | 6,95 | 0,48 | 1,07 | 55 | 10 | 38 | 1,27 | 1,75 | 8,00 | 201 |
| Rio Maior (3) | 7,50 | 6,90 | 1,20 | 1,27 | 56 | 27 | 50 | 1,34 | 1,38 | 0,00 | 147 |
| Carregueira (4) | 8,32 | 5,78 | 1,44 | 1,87 | 55 | 38 | 50 | 1,93 | 1,00 | 3,00 | 226 |
| Vale da Vila (5) | 2,33 | 2,61 | 0,89 | 1,48 | 62 | 51 | 50 | 1,41 | 1,15 | 10,00 | 297 |
| S. Martinho (6) | 1,61 | 2,93 | 0,54 | 3,97 | 56 | 6 | 59 | 1,13 | 1,46 | 0,00 | 254 |
| Óbidos (7) | 9,10 | 5,90 | 1,54 | 1,60 | 55 | 14 | 70 | 1,14 | 1,00 | 9,00 | 288 |
| Lagoa (8) | 7,98 | 14,00 | 0,58 | 2,46 | 57 | 23 | 81 | 1,18 | 1,97 | 16,00 | 70 |
| Telões (9) | 3,31 | 8,00 | 0,41 | 1,13 | 59 | 6 | 67 | 1,39 | 2,12 | 10,00 | 142 |
| Anjeja (10) | 0,85 | 2,13 | 0,40 | 1,48 | 58 | 11 | 27 | 1,19 | 1,40 | 0,00 | 74 |
| Beduído (11) | 1,40 | 3,82 | 0,37 | 2,44 | 58 | 11 | 27 | 1,17 | 1,40 | 31,00 | 160 |
| Canelas (12) | 3,59 | 5,57 | 0,65 | 4,15 | 58 | 11 | 27 | 1,21 | 1,40 | 57,00 | 35 |
| Fermelã (13) | 2,17 | 4,40 | 0,49 | 2,81 | 58 | 11 | 27 | 1,24 | 1,40 | 0,00 | 87 |
| Ilha Nova (14) | 2,25 | 2,73 | 0,83 | 2,79 | 58 | 11 | 27 | 1,12 | 1,40 | 71,00 | 32 |
| Rio das Mós (15) | 1,55 | 3,41 | 0,45 | 3,49 | 58 | 11 | 27 | 1,16 | 1,40 | 10,00 | 46 |
| Salreu (16) | 1,95 | 5,13 | 0,38 | 2,38 | 58 | 11 | 27 | 1,15 | 1,40 | 42,00 | 54 |
| Golegã (17) | 7,65 | 2,76 | 2,77 | 2,96 | 56 | 41 | 54 | 1,12 | 1,30 | 0,00 | 246 |
| Alquerubim (18) | 0,72 | 2,70 | 0,27 | 1,71 | 56 | 41 | 54 | 1,84 | 1,40 | 10,30 | 112 |
| Agueda (19) | 0,35 | 1,76 | 0,20 | 1,62 | 59 | 24 | 27 | 1,42 | 1,40 | 14,20 | 70 |
| Lamas (20) | 0,51 | 1,88 | 0,27 | 2,88 | 61 | 16 | 18 | 1,36 | 1,40 | 13,20 | 44 |
| Mean | 3,42 | 4,94 | 0,72 | 2,24 | 57,63 | 19,05 | 46,42 | 1,33 | 1,43 | 15,79 | 148 |
| St. Deviation | 2,93 | 3,06 | 0,62 | 0,94 | 2,17 | 14,09 | 20,74 | 0,25 | 0,27 | 19,66 | 104 |
| Var. Coefficient | 85,66 | 61,85 | 86,92 | 42,08 | 3,76 | 73,97 | 44,68 | 18,49 | 18,65 | 124,56 | 70 |

List of variables:

AFS – average farms size; ANP – average number of plots per farm; APS – average plots size; APD – average distance from farmstead centre to plots; AGE – average age of the farmers; EDUC – percentage of farmers with more than four years of scholar education; FED – percentage of farmers that are exclusively dedicated to farming; PS Coef. – average plots shape coefficient (this coefficient estimates the increase of tillage time due to the shape class of the plot in relation to normal time consumed on a one hectare 2/1 rectangular plot); RQ Coef. – average farm roads quality coefficient (this coefficient estimates the increase of travel time due to the quality class of the road in relation to time required to cover the same distance at a normal speed – 13 km/hour); UNC – percentage of uncultivated land in the total area covered by the LC project; REV – average farm revenue per hectare ($10^3$ escudos =1 cts ≈ 5 euros).



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**Table 3.** Total area, amounts of investment and characterization of the final situation of the twenty LC projects (situation after LC - simulated scenario).

| LC project (nº) | Tot. Area (ha) | INVEST. (cts/ha) | AFS (ha) | ANP | APS (ha) | APD (km) | PS Coef. | RQ Coef. | UNC (%) | REV (cts/ha) |
|---|---|---|---|---|---|---|---|---|---|---|
| Valença (1) | 300 | 1 881 | 2,29 | 5,40 | 0,37 | 0,72 | 1,13 | 1,15 | 1,00 | 540 |
| Samodães (2) | 305 | 2 326 | 3,34 | 2,87 | 1,16 | 0,70 | 1,00 | 1,33 | 0,00 | 635 |
| Rio Maior (3) | 2 110 | 446 | 8,78 | 3,22 | 2,73 | 1,00 | 1,12 | 1,00 | 0,00 | 211 |
| Carregueira (4) | 1 765 | 1 794 | 8,32 | 3,92 | 2,09 | 1,70 | 1,06 | 1,00 | 1,00 | 375 |
| Vale da Vila (5) | 978 | 2 963 | 2,33 | 1,35 | 1,73 | 1,26 | 1,00 | 1,03 | 0,00 | 866 |
| S. Martinho (6) | 610 | 1 037 | 1,98 | 1,56 | 1,27 | 3,45 | 1,00 | 1,00 | 0,00 | 355 |
| Óbidos (7) | 1 665 | 2 562 | 9,10 | 3,61 | 2,49 | 0,84 | 1,00 | 1,00 | 3,00 | 506 |
| Lagoa (8) | 2 083 | 368 | 7,98 | 9,00 | 0,87 | 2,42 | 1,06 | 1,00 | 10,00 | 98 |
| Telões (9) | 2 352 | 186 | 3,31 | 5,00 | 0,66 | 1,10 | 1,09 | 1,46 | 6,00 | 190 |
| Anjeja (10) | 87 | 1 232 | 0,85 | 1,13 | 0,74 | 1,44 | 1,09 | 1,00 | 0,00 | 143 |
| Beduído (11) | 175 | 2 396 | 1,40 | 1,10 | 1,32 | 2,41 | 1,05 | 1,00 | 31,00 | 326 |
| Canelas (12) | 500 | 1 653 | 3,59 | 1,70 | 2,12 | 3,66 | 1,05 | 1,00 | 0,00 | 217 |
| Fermelã (13) | 530 | 1 688 | 2,17 | 1,53 | 1,41 | 2,77 | 1,09 | 1,00 | 0,00 | 194 |
| Ilha Nova (14) | 160 | 887 | 2,25 | 1,55 | 1,46 | 2,80 | 1,07 | 1,00 | 46,00 | 102 |
| Rio das Mós (15) | 413 | 1 905 | 1,55 | 1,24 | 1,24 | 3,50 | 1,07 | 1,00 | 1,00 | 224 |
| Salreu (16) | 769 | 1 628 | 1,95 | 1,94 | 1,94 | 2,39 | 1,09 | 1,00 | 24,00 | 197 |
| Golegã (17) | 5 800 | 274 | 9,19 | 1,40 | 6,56 | 3,09 | 1,03 | 1,00 | 0,00 | 282 |
| Alquerubim (18) | 1739 | 274 | 1,57 | 1,76 | 0,89 | 1,69 | 1,09 | 1,00 | 2,40 | 158 |
| Agueda (19) | 360 | 688 | 0,48 | 1,19 | 0,40 | 1,44 | 1,08 | 1,00 | 2,30 | 144 |
| Lamas (20) | 243 | 714 | 0,78 | 1,46 | 0,54 | 3,12 | 1,06 | 1,00 | 0,01 | 119 |
| Mean | 1 194,77 | 971 | 4,00 | 2,74 | 1,73 | 2,05 | 1,06 | 1,05 | 6,97 | 312 |
| St. Deviation | 1 348,78 | 841 | 3,07 | 2,06 | 1,37 | 1,02 | 0,04 | 0,13 | 13,14 | 206 |
| Var. Coefficient | 112,89 | 87 | 76,84 | 75,16 | 79,24 | 49,47 | 3,87 | 12,43 | 188,55 | 66 |

List of variables:

Tot. Area- total area of the LC project perimeter; INVEST. – total volume of investment estimated for the realization of the project, express in contos per hectare ($10^3$ escudos =1 cts ≈ 5 euros) ; AFS – average farms size; ANP – average number of plots per farm; APS – average plots size; APD – average distance from farmstead centre to plots; PS Coef. – average plots shape coefficient (this coefficient estimates the increase of tillage time due to the shape class of the plot in relation to normal time consumed on a one hectare 2/1 rectangular plot); RQ Coef. – average farm roads quality coefficient (this coefficient estimates the increase of travel time due to the quality class of the road in relation to time required to cover the same distance at a normal speed – 13 km/hour); UNC – percentage of uncultivated land in the total area covered by the LC project; REV – average farm revenue per hectare ($10^3$ escudos =1 cts ≈ 5 euros).



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**Table 4.** Main changes achieved with the realization of the projects (situation after minus situation before the execution of the project).

| LC project (nº) | ∆AFS (%) | ∆ANP (%) | ∆APS (%) | ∆APD (%) | ∆PS Coef (%) | ∆RQ Coef (%) | ∆CAS (%) | ∆REV/ha (%) |
|---|---|---|---|---|---|---|---|---|
| Valença (1) | 21,16 | -43,16 | 146,67 | -40,30 | -35,80 | -24,34 | 10,00 | 42 |
| Samodães (2) | 0,00 | -58,71 | 141,67 | -34,58 | -21,26 | -24,00 | 8,00 | 216 |
| Rio Maior (3) | 17,07 | -53,33 | 127,50 | -21,26 | -16,42 | -27,54 | 0,00 | 44 |
| Carregueira (4) | 0,00 | -32,18 | 45,14 | -9,09 | -45,08 | 0,00 | 2,00 | 66 |
| Vale da Vila (5) | 0,00 | -48,28 | 94,38 | -14,86 | -29,08 | -10,43 | 10,00 | 192 |
| S. Martinho (6) | 22,98 | -46,76 | 135,19 | -13,10 | -11,50 | -31,51 | 0,00 | 40 |
| Óbidos (7) | 0,00 | -38,81 | 61,69 | -47,50 | -12,28 | 0,00 | 6,00 | 76 |
| Lagoa (8) | 0,00 | -35,71 | 50,00 | -1,63 | -10,17 | -49,24 | 6,00 | 40 |
| Telões (9) | 0,00 | -37,50 | 60,98 | -2,65 | -21,58 | -31,13 | 4,00 | 34 |
| Anjeja (10) | 0,00 | -46,95 | 85,00 | -2,70 | -8,40 | -28,57 | 0,00 | 93 |
| Beduído (11) | 0,00 | -71,20 | 256,76 | -1,23 | -10,26 | -28,57 | 0,00 | 104 |
| Canelas (12) | 0,00 | -69,48 | 226,15 | -11,81 | -13,22 | -28,57 | 57,00 | 520 |
| Fermelã (13) | 0,00 | -65,23 | 187,76 | -1,42 | -12,10 | -28,57 | 0,00 | 123 |
| Ilha Nova (14) | 0,00 | -43,22 | 75,90 | 0,36 | -4,46 | -28,57 | 25,00 | 219 |
| Rio das Mós (15) | 0,00 | -63,64 | 175,56 | 0,29 | -7,76 | -28,57 | 9,00 | 387 |
| Salreu (16) | 0,00 | -62,18 | 410,53 | 0,42 | -5,22 | -28,57 | 18,00 | 265 |
| Golegã (17) | 20,13 | -49,28 | 136,82 | 4,39 | -8,04 | -23,08 | 0,00 | 15 |
| Alquerubim (18) | 118,06 | -34,81 | 234,52 | -1,17 | -40,76 | -28,57 | 7,90 | 41 |
| Agueda (19) | 37,14 | -32,39 | 100,00 | -11,11 | -23,94 | -28,57 | 11,90 | 106 |
| Lamas (20) | 52,94 | -22,34 | 100,00 | 8,33 | -22,06 | -28,57 | 13,19 | 170 |
| Mean | 12,45 | -49,10 | 144,85 | -11,00 | -17,75 | -25,18 | 9,20 | 138 |
| St. Deviation | 27,93 | 12,75 | 90,31 | 14,92 | 12,13 | 11,19 | 13,40 | 135 |
| Var. Coefficient | 224,37 | -25,97 | 62,34 | -135,71 | -68,31 | -44,46 | 145,62 | 98 |

List of variables:

∆AFS – estimated change in the average farms size; ∆ANP – estimated change in average number of plots per farm; ∆ APS – estimated change in average plots size; ∆ APD – estimated change in average distance from farmstead centre to plots; ∆PS Coef. – estimated change in average plots shape coefficient; ∆RQ Coef. – estimated change in average farm roads quality coefficient; ∆CAS – estimated change in percentage of cultivated area surface in the total area covered by the LC project; ∆REV/ha – estimated change in average farm revenue per hectare.

Note: Positive values traduces change increases and negative values change decreases or reductions in a specific variable.

From the reading of Table 4 we can retain as essential and characteristic aspects of a Land consolidation action the significant increases in the average farms area (AFA), average plots size (APS), cultivated area surface (CAS) and, in particular, the average farm revenue (REV). Conversely, there is also a very significant reduction in the average number of plots (ANP), average distance from farmstead center to plots (APD), average plots shape coefficient (PS

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Coef.) and average road quality coefficient. (RQ Coef.). All of this clearly points to a significant improvement in the structural and infrastructural conditions for carrying out agricultural activity within the perimeters studied, because of the hypothetical implementation of the land consolidation action.

For the purposes of the following analysis, we have retained a total of 11 variables:

- the 8 of the Table 4, concerning the variations estimated as a result of the hypothetical realization of the investment project; and,
- three more concerning the volume of total investment (INVEST) and the labor and human environment for the realization of projects (EDUC - percentage of farmers with more than four years of scholar education; and EDF - percentage of farmers that are exclusively dedicated to farming).

## THE MODEL

Before proceeding to the estimation of the linear regression model, let us analyze the correlation matrix of the 11 variables considered. This matrix reflects the relationship of each variable to the others, i.e., it determines the correlations between variables to a significance level $\alpha = 0.05$. The results shown in Table 5, as well as all that follow, come from the statistical treatment of the data for the 20 cases using the software "STATISTICA", version 10.0.

**Table 5.** Correlation matrix of studied variables (the correlations bold marked are significant at the p level < 0,05).

| | ΔAFS | ΔANP | ΔAPS | ΔAPD | ΔPS Coef. | ΔRQ Coef. | ΔCAS | ΔREV | INVEST | EDUC | FED |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ΔAFS | 1,00 | **0,45** | 0,14 | 0,18 | **-0,49** | -0,14 | -0,06 | -0,28 | -0,37 | 0,00 | -0,14 |
| ΔANP | | 1,00 | **-0,63** | 0,06 | **-0,45** | 0,13 | -0,22 | **-0,51** | **-0,46** | 0,26 | 0,24 |
| ΔAPS | | | 1,00 | 0,22 | 0,21 | -0,21 | 0,27 | 0,40 | 0,20 | -0,29 | -0,41 |
| ΔAPD | | | | 1,00 | 0,22 | -0,42 | 0,02 | 0,09 | **-0,49** | 0,08 | **-0,49** |
| ΔPS Coef. | | | | | 1,00 | -0,34 | 0,11 | 0,29 | -0,10 | -0,29 | -0,24 |
| ΔRQ Coef. | | | | | | 1,00 | -0,09 | -0,01 | **0,54** | **0,45** | -0,02 |
| ΔCAS | | | | | | | 1,00 | **0,80** | 0,09 | -0,17 | -0,28 |
| ΔREV/ha | | | | | | | | 1,00 | 0,36 | -0,18 | **-0,53** |
| INVEST | | | | | | | | | 1,00 | 0,04 | -0,06 |
| EDUC | | | | | | | | | | 1,00 | 0,08 |
| FED | | | | | | | | | | | 1,00 |

List of variables:

ΔAFS – estimated change in the average farms size; ΔANP – estimated change in average number of plots per farm; Δ APS – estimated change in average plots size; Δ APD – estimated change in average distance from farmstead centre to plots; ΔPS Coef. – estimated change in average plots shape coefficient; ΔRQ Coef. – estimated change in average farm roads quality coefficient; ΔCAS – estimated change in percentage of cultivated area surface in the total area covered by the LC project; Δ REV – estimated change in average farm revenue per hectare; INVEST – total volume of investment estimated for the realization of the project, express in contos per hectare ($10^3$ escudos =1 cts ≈



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5 euros); EDUC – percentage of farmers with more than four years of scholar education; FED – percentage of farmers that are exclusively dedicated to farming.

The significant (p level < 0,05) correlations between variables that were found are:

- between the increase of the average farms size and the reduction of the average number of plots (ΔAFS↔ΔANP) and the average plots shape coefficient (ΔAFS↔ΔPS Coef.), i.e., increased exploitation tends to lead to an improvement of its land structure;
- between the reduction of the average number of plots and the increase of the average plots size (ΔANP↔ΔAPS) and the reduction of the average plots shape coefficient (ΔANP↔ΔPS Coef.), that is, the reduction of the number of plots allows the increase of the area and the improvement of the form of the remaining plots;
- between the reduction of the average distance from farmstead centre to the plots and the increase of the volume of investment (ΔAPD↔ΔINVEST) and the percentage of farmers that are exclusively dedicated to farming (ΔAPD↔ΔFED). This can be interpreted by the fact that much of the investment volume is associated with the rehabilitation and construction of the road network, and also by the fact that a larger percentage of exclusive farmers means greater potential benefits from a new spatial arrangement (usually exclusive farmers are also those with larger and more fragmented holdings);
- between the reduction of the roads quality coefficient and the increase of the volume of investment (ΔRQ Coef.↔ΔINVEST), which can be interpreted, as already mentioned, because much of the investment volume is associated with the recovery and construction of the new road network;
- the correlation between the reduction of the roads quality coefficient and the increase of the percentage of farmers with more than four years of scholar education (ΔRQ Coef.↔ΔEDUC), is much harder to understand and, above all, to justify;
- between the increase of the cultivated area surface and the increase of the average farm revenue (ΔCAS↔ΔREV). This is a direct consequence of the reduction in uncultivated spaces, and above all as a result of the investments made in the improvement or construction of the new drainage network;
- and, lastly, between the increase of the average farm revenue and the increase of the percentage of farmers that are exclusively dedicated to farming (ΔREV↔FED), which reflects the fact that it is this type of farmer who benefits most and benefits from the overall improvements introduced by the LC projects.

The most evident correlation is that established between the ΔREV and the ΔCAS, since it is the one with the highest value, in modulus, of the correlation coefficient, which means that such a relationship is approximate by a linear type structure.

It is important to keep in mind, however, that when studying the relationship between any two variables, say x and y, a high value for r does not always mean that x is the cause of y or vice



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versa. To state, therefore, that there is correlation between two variables does not allow us to say that there is a causal relationship between them. An example of this is the correlation between the variables ΔRQ Coef. and EDUC, whose causal relationship is, as we have seen, very difficult to understand.

Therefore, we also understand that it would be important to test for correlation between the total variable area of the project perimeter and the total and unitary amount of investments. However, as the following figure shows, such a correlation has no statistical significance.

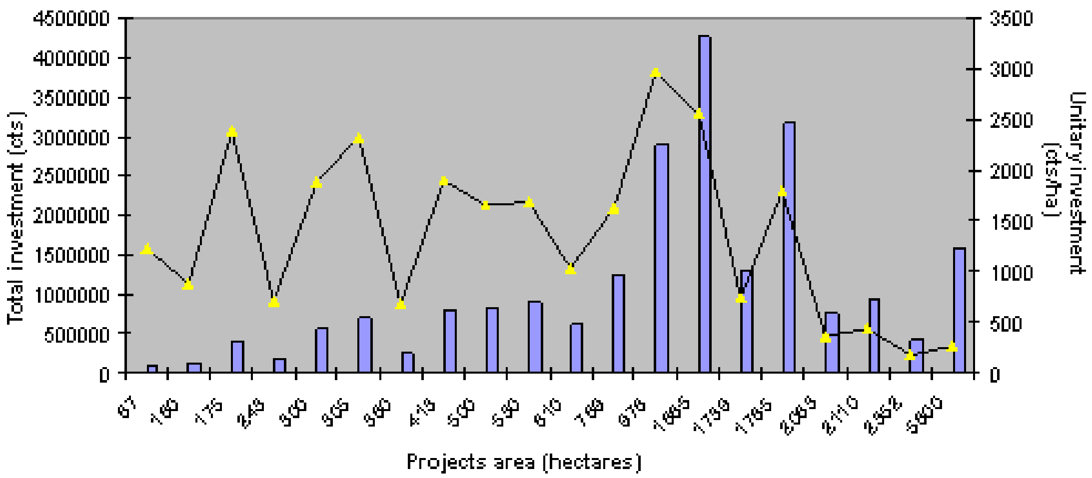


**Fig. 1.** Variation of the total and unitary investments in relation to the projects areas.

The regression model we will try to estimate uses the variable average farm revenue per hectare (REV/ha) as the dependent or response variable.

Then we present the outputs resulting from the "run" of the statistical program, on the base data. There is one aspect, however, that should be highlighted: in the estimation of the model, it makes no sense that the regression line does not go through the origin, since, in the presence of variables that represent percentage variations, it is logical that in situations where variation of the predictive variables is null there is no change or variation of the response variable (in this case the REV/ha). We must therefore assume that zero variations of the predictive variables correspond, of course, to zero variations in yields. Thus, the model, conditioned to a zero origin ordinate ($\beta_0 = 0$), will take the simplified form of:

$$Y_i = \beta_1 * x_{1i} + \beta_2 * x_{2i} + \ldots\ldots\ldots + \beta_p * x_{pi} + e_i.$$

By running the program to estimate the complete model (10 predictive variables), we obtained the results presented in the following table (Table 6) and figure (Figure 2).

**Table 6**. Multiple linear regression (*forward method*) for the dependent variable change in farm revenue per hectare (Δ REV/ha).

R= ,97036328; R²= ,94160490; Adjusted R²= ,88320980; F(5,14)=18,217; p<,00001; Std. Error of estimate: 55,762

| | BETA | St. Err.of BETA | B | St. Err.of B | t(14) | p-level |
|---|---|---|---|---|---|---|
| Δ AFS | -0,05581892 | 0,15137578 | -0,33579167 | 0,91063618 | -0,36874404 | 0,72000551 |
| Δ ANP | -0,50101223 | 0,51487357 | -1,89739152 | 1,94988602 | -0,97307817 | 0,35346389 |
| Δ APS | -0,12575881 | 0,26116354 | -0,14280593 | 0,29656534 | -0,48153278 | 0,64050168 |
| Δ APD | 0,06797957 | 0,16339752 | 0,76416814 | 1,83677509 | 0,41603795 | 0,68616998 |
| Δ PS Coef. | 0,0326559 | 0,21811834 | 0,28935173 | 1,93266503 | 0,14971644 | 0,8839649 |
| Δ RQ Coef. | -0,16499621 | 0,32792384 | -1,11459888 | 2,21522383 | -0,50315407 | 0,62575257 |
| Δ CAS | 0,55984895 | 0,10449171 | 6,69200251 | 1,24901328 | 5,35783134 | 0,00032002 |
| INVEST | 0,39023217 | 0,26210045 | 0,04648904 | 0,03122449 | 1,48886497 | 0,16736685 |
| EDUC | 0,02429498 | 0,161684 | 0,21317628 | 1,41869634 | 0,15026209 | 0,88354546 |
| FED | -0,43172081 | 0,27829813 | -1,68203457 | 1,08428194 | -1,55128893 | 0,1518787 |

List of variables:

Δ AFS – estimated change in the average farms size; Δ ANP – estimated change in average number of plots per farm; Δ APS – estimated change in average plots size; Δ APD – estimated change in average distance from farmstead centre to plots; Δ PS Coef. – estimated change in average plots shape coefficient; Δ RQ Coef. – estimated change in average farm roads quality coefficient; Δ CAS – estimated change in percentage of cultivated area surface in the total area covered by the LC project; INVEST – total volume of investment estimated for the realization of the project, express in contos per hectare ($10^3$ escudos =1 cts ≈ 5 euros); EDUC – percentage of farmers with more than four years of scholar education; FED – percentage of farmers that are exclusively dedicated to farming.

The following figure shows the mismatch between the values estimated by the regression model and the values really observed. This is therefore a residue analysis based on a 95% confidence interval.

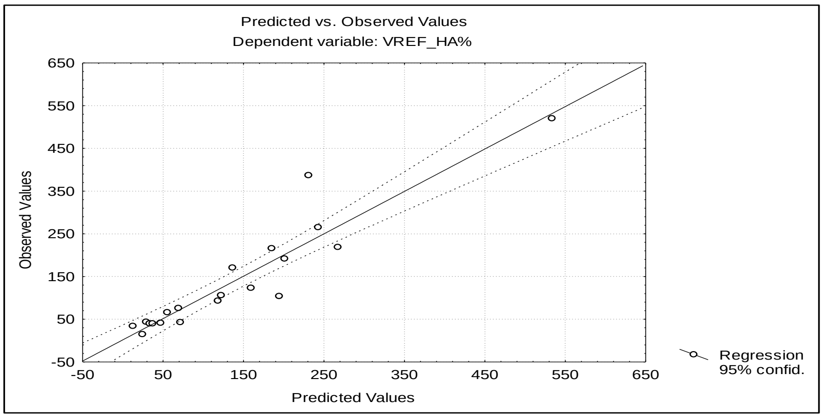


**Fig. 2.** Predicted versus observed values.
($10^3$ escudos =1 cts ≈ 5 euros)

The overall adjusted model explains 94% of the total REV/ha variability ($R^2$=0,9416), which can be considered very good, because when looking at the adjusted $R^2$ we find a very high value too (Adjusted $R^2$ = 0.8832). The associated p-level at the same time gives us a very good reliability of the model; however, the p-level associated with each of the variables no longer gives us such great security, which, in a way, raises the hypothesis of resorting to a more simplified model.

The hypothesis that we can achieve better results considering a smaller number of predictive variables was explored through the step-by-step forward method in search of a data-adjusted sub model. The main objective of looking for data-adjusted sub models is to try to come up with a simpler model than the original, in order to simplify it and facilitate its possible later use. After all, let us remind you, the great purpose of our work.

To choose a sub model adjusted to the data, it is not enough to choose the one with the highest coefficient of determination ($R^2$), as we would always be tempted to choose the final sub model, since the more variables one includes in the model, the greater its value explanatory power. At the same time, if the included variables do not add anything new to the model, the model may progressively lose significance despite increasing its explanatory power. Therefore, we have to guide ourselves in choosing the final sub model by the value of the p-level. This value gives us an idea of how plausible $H_0$ will be (where $H_0$: $0_j = 0$), i.e., it tells us how likely we are to make a Type I error, i.e., the probability of rejecting a null hypothesis. ($H_0$) which, in fact, is true.

Referring now to Table 7 we can see that by the setp-by-step forward method we arrive at a sub model incorporating 6 predictive variables, which explains approximately 93% of the total REV/ha variability. Increases in the sub model's explanatory capacity compared to the original model are noticeable. The only "snag" of the model is the "p-level" associated with the variables ΔAPD and ΔPS Coef, which present values in the 40% range, thus making $H_0$ more plausible, that is, if it is true $H_0$ (being $H_0$ of the type, $H_0$: $\beta_j$=0), in 2 out of 5 experiments it reaches as much or more extreme than that associated with tn-p '($\alpha$/2), thus reinforcing the truth of $H_0$ and thus we should not enter these variables into the model.

Nevertheless, our choice lies with this sub model to explain the variability of REV/ha as it has good explanatory capacity (close to 2% increase in adjusted $R^2$) and an excellent value of "p-level ". It should not be forgotten that, by including more case studies, one may perhaps arrive at a model with better-fit, greater explanatory capacity and fewer variables and, above all, with better significance levels associated with each variable.



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**Table 7.** Multiple linear regression (*step by step forward method*) for the dependent variable change in farm revenue per hectare (ΔREV/ha).

R= ,96746; $R^2$= ,93598; Adjusted $R^2$= ,90854; F(6,14)=34,114; p<,00000; Std. Error of estimate: 57,231

| STEP nº | VARIABLE | BETA | St. Err. of BETA | B | St. Err. of B | t(13) | p-level |
|---|---|---|---|---|---|---|---|
| 1 | ΔCAS | 0,56644663 | 0,08906279 | 6,77086608 | 1,06458795 | 6,36008146 | 0,000017683 |
| 2 | INVEST | 0,38087671 | 0,19523061 | 0,04537451 | 0,02325816 | 1,95090677 | 0,07137539 |
| 3 | ΔAPD | 0,09529718 | 0,11513348 | 1,07124932 | 1,29423198 | 0,82771044 | 0,42172018 |
| 4 | ΔPS Coef. | 0,09722981 | 0,12837414 | 0,86151699 | 1,13747522 | 0,75739407 | 0,46137217 |
| 5 | ΔANP | -0,48272903 | 0,22564075 | -1,82815091 | 0,85452773 | -2,13936991 | 0,05050647 |
| 6 | FED | -0,29017702 | 0,18220352 | -1,13056347 | 0,70988613 | -1,59259833 | 0,13357092 |

List of variables:

Δ CAS – estimated change in percentage of cultivated area surface in the total area covered by the LC project; INVEST – total volume of investment estimated for the realization of the project; Δ APD – estimated change in average distance from farmstead centre to plots; ΔPS Coef. – estimated change in average plots shape coefficient; Δ ANP – estimated change in average number of plots per farm; FED – percentage of farmers that are exclusively dedicated to farming.

## CONCLUSIONS

Let us remind that the main purpose of this paper is to develop a decision-making support tool, to aid the preordination and selection of the submitted LC projects will proposals. This is viewed as a critical issue because in Portugal, we are under a situation where the demand for Integrated Land Consolidation actions clearly exceeds the available public resources, either human or economic, affected to do it. Additionally, the usual method of performing de ex-ante evaluation of the LC projects in the previous study fase in Portugal (Coelho, 1992), although having proved to be consistent and accurate, is a heavy and long time consuming one. Given so, the pertinent question that should be asked is how to simplify the process without omitting any important component?

In this paper, we explore the hypothesis of using a multiple linear regression model to capture and explain a significant part of the variability of the economic results driven by LC actions, and we present a case study, based on twenty previous studies of LC actions carried out in Portugal in the last three decades.

The main objective of this work is to try to establish a regression model that allows us to estimate, ex ante, the magnitude of the increase in economic results due to changes made in some easily measurable variables, with the realization of LCPs.

To establish the model we started from a database, built based on information from 20 reports of previous studies of LCPs. To estimate the regression model we used the software STATISTICA version 10.0. In addition to the complete model (incorporating 10 predictive and 1 dependent variables), we also studied, based on the step-by-step forward statistic method technique, a simpler sub model, incorporating only 6 predictive variables.

In general terms, it seems to me to point out the following conclusions:

- We have found quite significant correlations between several variables:
  - positive, or direct, and statistically significant, correlations were found between the following variables: average farms size (ΔAFS) and average number of plots per farm (ΔANP); average roads quality coefficient (ΔRQ Coef.) and total volume of investment estimated for the realization of the project (ΔINVEST); the percentage of farmers with more than four years of scholar education (ΔEDUC) and the cultivated area surface (ΔCAS) and average farm revenue per hectare (ΔREV/ha).
  - negative, or inverse, and statistically significant correlations were found between the following variables: the average farms size (AFS) and the average farm roads and the quality coefficient (RQ Coef.); the average number of plots per farm (ANP) and the average plots size (APS), the average plots shape coefficient (PS Coef.), the average farm revenue per hectare (REV/ha) and the volume of unitary investment estimated for the realization of the project (INVEST); and, between the average distance from farmstead centre to plots (APD) and the volume of unitary investment estimated for the realization of the project (INVEST) and the percentage of farmers that are exclusively dedicated to farming (FED).

- In an attempt to explain, by means of a multiple regression model, the variability of the REV/ha increment over these 11 variables, we came up with a final sub model that included 6 variables and explains over 94% of the total variability of the increment. REV/ha; The variables that have the highest explanatory capacity for the increases in REV/ha are:
  - the increase in the cultivated area surface (CAS);
  - the increase in the percentage of farmers who are exclusively dedicated to farming (EDF);
  - the volume of unitary investment estimated for the realization of the project (INVEST); and,
  - the reduction of the average number of plots per farm (ANP).

- We also managed to come up with a simpler sub model based on only 6 variables, which nonetheless can account for more than 93% of the total variability of REV/ha increase; In this case, the variables with the greatest explanatory capacity for the increases recorded in REV/ha are, logically: the increase in the cultivated area surface (CAS) and the volume of unitary investment estimated for the realization of the project (INVEST).



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Before we finish, we would like to draw attention to possible future developments of this work, because by including more observations, even better models can be achieved: simpler and more explanatory. The basic idea has been launched, and now, if it has a minimum of reception, it is necessary to continue the work of improving the model and testing its adherence to reality.

Finally, we point out that the great advantage of this type of model is that they can replace the current (heavy, complex and time-consuming) study and evaluation methodology of LCP in the Preliminary Study phase. However, at other later stages of the LCP, we continue to place more confidence in the methodology that has been used for some years now.

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