# SUSTAINABLE AGRICULTURE-
# POLAND AND PORTUGAL


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## PREFACE

Until very recently the role of agriculture was mainly associated with the production of food and fibbers. More recently, agricultural activities have become more diverse and there was an increase in the use of agricultural products or sub-products for energy production, such as the use of biomass for combustion, gasification, pyrolysis, etc. In some cases this allowed the increase of the efficiency and sustainability of this activity and decreased its impact in the environment. Efficiency in the use of primary agricultural resources (soil, water) and agricultural inputs (fertilizers, energy, pesticides) has also being a major concern overtime. Some agricultural resources became scarcer, improvements in agricultural technology can no longer increase yields in many crops, and there is a high level of competitiveness, which requires great levels of efficiency in the use of agricultural inputs in order to achieve higher yields, or the same yields with lower costs and lower environmental impacts.

The current globalization of the economy, apart from reducing geographic seasonality of agricultural products also poses new issues that did not exist a few years ago, for example; nutrient transport between different countries via the global transport of food; relocation of new agricultural pests and diseases; and biosecurity associated with the emergence of new genetically modified species.

Food security is nowadays a major concern for most of the countries in the world. Therefore there is a worldwide need to increase productivity, which in the richest and more developed countries is combine with the promotion of a strong agro-industrial sector, characterized by a high level of technological development and, that way, becoming more productive per unit of used production factor, increasing its sustainability in the medium and long-run.

Currently the agricultural sector has also being assigned with other functions related to the protection, promotion, enjoyment and cohesion of the natural countryside landscape, as well as an activity allowing the fixation of populations and an guarantor of social cohesion and balance.

Nature, landscape, food, fibber, energy, agribusiness, economy, efficiency, food safety, biosecurity, sustainability, value and social cohesion, among others, are some of the functions that we might associate with farming and surely in the next future other new features can be added. Given the above and in order to reflect on the current and future multiple functions of farming, we gathered in this publication thematic visions of Portuguese and Polish experts on different agricultural related activities, most of each were presented in the Workshop "Agriculture Sustainability, Poland-Portugal", that took place in the University of Évora, Portugal, in December 2013. This action tried to develop an integrationist exercise, in a diverse and plural Europe, that at the same time self-builds with exercises such as this. Finally, we also want to  thank the work of the scientific reviewers, which allowed improving the quality of the book.

*The editors*

## FOREWORD

Revisiting and possibly revising some of the tenets of economic policies in the past 10 years will probably become an experience of many European countries. Reviving national economies after the crisis of the first decade of 21. Century is not a small feat. Poland and Portugal, among many cultural characteristics which its people have in common, share also the structural-historical nature of their respective societies -they were both predominantly peasant, agrarian economies for most part of the twentieth century. Even when undergoing rapid urbanization and industrialization, both countries not only depend on their agricultural production but also have a substantial developmental potential in the agrarian sector. Today, in the second decade of the twenty-first century, and having lived through intensive and profound European integration processes, as well as having experienced an economic crisis of the modern era, our two societies are looking with the renewed interest at the issue of agricultural development. Europe, as the union of 28 countries, is entering a new stage of development that most likely will involve some change of previously taken for granted presumptions. Sustainable agricultural development, re-industrialization, re-urbanization, re-allocation of populations to sub-urban and rural areas and re-training will probably be among many major tasks. Establishing the sustainable agricultural development will be, in my opinion, a prominent task. It may blow new life into depopulated areas, it will revitalize small towns and service centers, it will create new social class of educated growers and consumers and, in the end of the day may become a propelling mechanism for not only national economies, but for supra-national regions as well.

The initiative undertaken by scholars and researchers from Évora (Portugal) and Lublin (Poland) with the substantial support from the Embassy of the Republic of Poland in Lisbon brings fruit in the form of this volume. This is but the first chapter of investigations and ruminations about what lies ahead of us. The sustainable development is an answer to many problems of contemporary economies, and a challenge that we have to confront and undertake.

*Prof. Bronislaw Misztal*
The Ambassador of the Republic of Poland to Portugal

Sustainable agriculture is a condition for the survival of mankind. If one wants to preserve the soil and water availability and quality so that future generations can be fed, it is an urgent matter that the principles of sustainable agriculture be applied right now and all over the world. Research for sustainability is paramount to optimize the agriculture activity, such that, with due concern to the farmers' wellbeing, the focus is on sustainable production at high levels and not just on immediate productivity. This is not a question of survival against profit. In fact, if we think in the long term, the two are not incompatible and sustainable profit from agricultural activity can only be achieved if we can achieve agriculture sustainability. Poland and Portugal, having quite relevant agricultural sectors, share a common interest in research and development in this area. The University of Évora, since it's very restart 40 years ago, has given much attention to research on agriculture sustainability and the dissemination to the farmers of the developed methodologies, at a time when the subject was ignored by most research facilities. Its research center ICAAM is well-known for its activity in that area. The University of Lublin has similar concerns.

Professor Bronisław Misztal, Ambassador of Poland, has the advantage of being both a brilliant academic and an open minded Ambassador with a broad view for the future of the cooperation between our two countries. A high point in his agenda is to foster the cooperation between the academic communities, particularly in matters that can have a profound effect in our societies. When he visited the University of Évora and proposed that we strive for that agenda, starting with joint Colloquia for the mutual knowledge of both countries' reality and research under way, my suggestion was that we start with agricultural sustainability for all the good reasons referred to above. Of course, others are being planned on different subjects but the success of this first experience will certainly help the organization of future events. Besides the exchange of experiences, which is very important for future research development, it is our hope that this activity will also help in the development of joint research projects of common interest, possibly with the participation of other partners as well, and in strengthening the success of the research teams in granting funds to develop such projects.

I am very grateful to the organizers, invited speakers and to all participants for their efforts in making this event a very successful one. I am particularly grateful to the Embassy of the Republic of Poland for the generous support of this event and to the Ambassador, Professor Bronisław Misztal, a good friend of mine and of the University of Évora, for this program of cooperation and for his continuing personal support and efforts.

*Prof. Carlos Braumann*

Rector of the University of Évora at the time

## NOTATION

| Abbreviation/ symbol | Description/explanation |
|---|---|
| € | Euro |
| AL | Agricultural Land |
| ATV | All Terrain Vehicle |
| AWU | annual working unit |
| *C* | *carbon afflux from soil and biomass into atmosphere* |
| *c.e.c.* | cation exchange capacity |
| CAP | Common Agricultural Policy |
| CHP | Combined Heat and Power (cogeneration) |
| CRA-W | Agricultural Research Centre, Gembloux, Belgium |
| CU | Cereal Unit |
| CV | coefficient of variation |
| CVT | Continuously Variable Transmissions |
| *D* | *measure of soil degradation* |
| *E* | *total energy input* |
| EAR | Energy Autonomous Region |
| EEC | European Economic Community |
| ESU | European Size Unit |
| EU | European Union |
| FEC | final energy consumption |
| GAP | Good Agricultural Practice |
| GDP | Gross Domestic Product |
| GHG | greenhouse gas |
| GIOR | Główny Inspektorat Ochrony Roślin i Nasiennictwa (Main Inspectorate of Plant and Seed Protection) |
| GIS | Geographic Information System |
| GJ | gigajoule |
| GPS | global positioning system |
| GVA | gross value added |
| ha | Hectare |
| HP | horse power |
| hrs | hours |
| *If* | *annual income of an agricultural family (PLN/ha AL)* |
| *Imb* | *mean monthly income per one worker in the budgetary sphere (PLN)* |
| IT | information technology |
| kW | kilowatt |
| kWh | kilowatt-hour |
| l | liter |
| LU | Large Unit |

| | |
|---|---|
| m | meter |
| man-h | man hours |
| MJ | megajoule |
| mln | million |
| mm | millimeter |
| *n* | *number of  convertible family members employed in a farm* |
| o.m. | organic matter |
| OECD | The Organisation for Economic Co-operation and Development |
| *P* | *agronomic productivity* |
| PAAC | Provincial Agricultural Advisory Centre |
| PEC | primary energy consumption |
| PIMR | Przemysłowy Instytut Maszyn Rolniczych (Industrial Institute of Agricultural Engineering), Poznań, Poland |
| PJ | petajoul |
| PL | Poland |
| PLN | Polish Zloty |
| PT | Portugal |
| *Q ha AL* | *parity area of farm (ha AL)* |
| RPU | Single Payment Scheme |
| *S* | *Sustainability* |
| SA | Sustainable Agriculture |
| SCR | Selective Catalytic Reduction |
| t | tonne |
| *t* | *time* |
| thous. | thousand(s) |
| VMD | volume median diameter |
| *W* | *water quality* |

# 1. THE EVOLUTION OF THE PORTUGUESE AGRICULTURE IN THE CONTEXT OF THE EUROPEAN UNION

*Carlos A. Falcão Marques*

**Keywords:** *Portugal, agriculture, CAP, reform, impacts*

## 1.1. Introduction

Portugal joined the European Economic Community (EEC) in 1986, together with Spain. At the time, this enlarged the number of member states to 12. With the fall of the Berlin wall, starting with the Germany unification, and the dismantling of The Soviet Republic Union, the already called European Union (EU) reached out to eastern European countries to grab the political opportunity to put together, progressively, a broader democratic Europe. Poland became an EU member together with a number of these countries in 2004.

Today the EU has 28 member states. Each country's integration process has its own peculiarities due to several factors, including structural characteristics of their economy and policies for different economic sectors and differences to countries with which they will have to compete. But, this is particular important to agriculture where a Common Agricultural Policy (CAP) applies.

The major objective of this chapter is to analyse and briefly describe the evolution of Portuguese agriculture in the context of the European Agriculture. It is not a comprehensive analysis. It is a sketch of its major changes due to major aspects that had influenced in particular the Common Agricultural Policy, and how has evolved with respect to changes in CAP orientation and reforms. This analysis provides an example that might be useful to understand what can be done in the future both in Portugal as in other countries In some aspects figures about these countries including Poland will be presented to benchmark the analysis.

Besides this introduction, the chapter has five additional sections. In the next section, background on the Portuguese agriculture and policy before accession is provided. Then, in the third, socio-economic structural characteristics of Portuguese agriculture and their evolution for the last four decades are briefly presented. In the fourth section analysis turns read and understand the evolution as major implications of changes in agricultural policy from CAP reforms. In the fifth section we turn to aspects that are the focus of post-2013 CAP reform and relate them to Portuguese status. Finally, as a conclusion, we look for CAP and the sustainable orientations for Portuguese farmers.

## 1.2. Portuguese agriculture and agricultural policy background

The evolution of Portuguese agriculture before and after the accession to the European Community is well documented in books, book chapters, reports and studies of the 80’s and 90’s decades and the beginning of this century referred in the introductory note of Avillez et al. (2004). Marques has been following and studying the evolution of Portuguese agriculture since the mid 80´s, in particular to derive the prospects and impact of CAP in the agriculture of the Alentejo region of Portugal.

At the time of the revolution of April, 1974, following a long period of five decades of dictatorship, agriculture was a backward sector. For decades the agricultural sector had been stagnant. Agricultural output was unable to meet other sectors growth and the country needs for food products and the sector was a constraint to development (Marques, 1998).

In addition, the agricultural sector was particularly affected, since the early years of democracy, by the event of an agrarian reform, particularly in the large farms of the South of Portugal, with land property becoming a political and law issue with major consequences for a long period of time (World Bank, 1984).

Policies to overcome the lack of response of production during this period of time, before the accession, were focused on increasing production with factor subsidies and increasing product prices (Truong and Josling, 1983). The Portuguese agriculture before EEC and its long time problems are characterized in detail in “Portuguese Agriculture in Transition” (Pearson, 1987).

In the EEC, at those times, high and stable target prices, institutionally set and maintained through import protection with variable levies, had encouraged production and took levels of the majority of agricultural product to self-sufficiency and, then, surpluses.

Hence, on the brink of Portugal accession to the EEC, Portuguese and EEC agricultural sectors had contrasting structural characteristics, productive and economic behaviors and policy needs. The point was that the EEC and the Portuguese agriculture were in different cycles.

Prices for crops in Portugal were 20 to 40 percent higher than EEC prices. For livestock products the gap was smaller. As a result, negotiations established, for products or systems that needed larger adjustments in prices, a two-stage scheme of freezing Portuguese prices in the first period in order to allow EEC prices to meet these prices and a second period of seven years adjustment steps to set the same price levels.

Reality would reveal these provisions to be tremendously out of site. Re-negotiations of the second period were necessary and postponed adjustments for more ten years, with decreasing specific payments adopted during that period as prices of EEC decreased and policies moved in the opposite direction. The Single European Market and the start of the Mac Shary reform of CAP in the mid-nineties brought full integration of Portuguese Agriculture with European partners and full adoption and implementation of CAP rules.

As we all know, then, we had CAP route to decoupling. First with compensatory payments based on historical production and potential levels, then with successively more products included. Agenda 2000 and Health check with the single payment scheme moved forward to an income support policy away from market prices and effects. Now, with CAP 2020 we are preparing to address inequality of countries, regions and farmers moving to a single payment per hectare more equitable support among farmers and countries, which means to deal with historical rights and remove product payment differences, as well as to a greener CAP.

**1.3. Evolution of structural indicators of Portuguese agriculture**

To understand how Portuguese agriculture has evolved during the last thirty years and dealt with these different phases and policy reforms we will look to major structural socio-economic figures through the agricultural censuses (table 1.1). As a starting point of the analysis we used 1968, as benchmark for agriculture before the revolution, and then we looked to 1989, 1999 and 2009 agriculture census. This analysis updates figures presented in previous studies following the evolution of the Portuguese agriculture (Marques, 1999, 2003).

Portuguese agriculture has experienced large and continuous decrease of agricultural producers. From more than eight hundred thousand, farms number decreased to below three hundred thousand. Roughly, since 1968, two out of each three small farms with less than 20 hectares and one out of each pair of farms with less than 100 ha no longer exist. This adjustment trend has been more moderate in the last years. The number of farms with more than 100 hectares has increased, steadily.

The same holds for land. Utilised agricultural area has registered moderate but continuous decrease from 4.1 to 3.5 million hectares. However, substantial change has happened in land use patterns. Permanente pastures substituted arable lands (which were used for temporary crops) at large rates. From 3.3 we are down to 1.2 million hectares utilized as arable land, with less 0.6 million hectares during each last decade. Permanent pasture land area increased 8 times, with more than 0.5 million hectares each last decade. Land used in permanent crops increased, then experienced a slight reduction and, more recently, a stabilization trend.

Table 1.1. Selected structural indicators of Portuguese Agriculture, 1968, 1989, 1999 and 2009

| **Farm Structural Indicators** | **Years** | | | |
|---|---|---|---|---|
| | **1968** | **1989** | **1999** | **2009** |
| **Number (thousand farms or agricultural producers)** | 811.7 | 550.9 | 382.2 | 278.1 |
| **Number of farms (thousand) by size** < 5 ha | 631.6 | 450.4 | 299.3 | 208.4 |
| 20 to 100 ha | 153.2 | 78.9 | 61.5 | 49.3 |
| > 100 ha | 22.2 | 16.3 | 15.6 | 14.4 |
| **Utilised agricultural area and composition (mln ha)** | 4.10 | 3.88 | 3.74 | 3.54 |
| Arable lands | 3.28 | 2.36 | 1.75 | 1.17 |
| Permanent crops | 0.60 | 0.78 | 0.71 | 0.69 |
| Permanent pastures | 0.22 | 0.74 | 1.28 | 1.68 |
| **Form of operation (thousand farms)** | | | | |
| Owned farms | 517.5 | 499.4 | 357.0 | 262.5 |
| Rented | 121.8 | 117.7 | 49.3 | 27.7 |
| Other forms | 172.3 | 53.0 | 38.5 | 20.9 |
| **Legal form (thousand farms)** | 810.9 | 550.1 | 381.1 | 277.1 |
| Individual producers | 810.3 | 546.1 | 375.9 | 270.5 |
| Firms | 0.6 | 3.7 | 5.2 | 6.6 |
| **Individual producers by age (thousand)** | 811.6 | 546.1 | 375.9 | 270.5 |
| Less than 35 years old | 87.0 | 34.9 | 14.2 | 5.3 |
| 35 to 65 years | 551.5 | 354.3 | 217.9 | 132.0 |
| More than 65 years | 173.1 | 156.8 | 143.8 | 133.2 |
| No formal education | 799.9 | 524.9 | 357.8 | 246.8 |
| High school education | 5.3 | 15.1 | 8.2 | 11.4 |
| Graduate education | 6.5 | 6.1 | 9.9 | 12.3 |

*Source: Instituto Nacional de Estatística, Agricultural Census, 1968, 1989, 1999 and 2009*

With respect to land ownership, a steadily decrease of the number of farms rented or operated under other forms has occurred in the last two decades and the relative number of owned operated farms has been increasing.

Individual producers still are the overwhelming majority of legal form of farms. Firm/company total number of farms is increasing in absolute and relative terms but is still a very low proportion of farms.

Structural indicators in terms of age and formal education of individual producers are particularly expressive. Dividing age classes in young, middle and old aged (less than 35, between, 35 and 65, and more than 65), the largest is the third group. Hence, human capital is made of very high and increasing relative proportion of aged producers. On the other hand, there is a low proportion of young producers and decreasing during time, which indicates that young people are still leaving agriculture. In addition, a very high proportion of producers have no formal school training (more than 90%) but high school and university graduates in agriculture have increased in absolute terms in the last two decades.

To understand the economic performance of the agricultural sector over the past the picture given by the Agriculture Economic Accounts is very clear (INE, CEA 1980-2006). Final agricultural production value measured in moving averages of three years has very low annual rate of real growth during the period. Agricultural gross added value to annual growth rate is null or slightly negative during the period, indicating real annual growth of cost of intermediate factors than final production value. Volume and labour productivity are very important to understand changes in Portuguese agriculture. In relation to volume of labour in agriculture, total equivalent annual working units (AWU) decreased from 1.22 to 0.34 million AWU during this period which suggests rates of annual decrease of labour volume of more than 4 percent per year leaving the agriculture. Hired labour force only makes 6 percent of total volume of labour. This reduction in labour volume of agriculture allowed for a large positive annual rate of change of net added value per unit of labour of 4 percent, i.e., a significant increase in labour productivity in agriculture during the period.

More recent economic indicators show that these indicators did not improve in more recent years. Figure 1.1 presents in the dark green line the evolution of Gross Added Value at constant prices from 2000 till 2013. In fact, the evolution since 2006 has even been more unfavourable.

Table 1.2. Selected economic indicators of Portuguese Agriculture, 1980/82 and 2004/06

| **Production, income and labour indicators** | **Moving averages of 1980/82 and 2004/06 (annual rate of growth)** |
|---|---|
| Final production value (at base and constant prices of year 2000) | 0.6 |
| Gross Added Value (at constant prices of year 2000) | -0.1 |
| Volume of labour (equivalent labour year units ELUs) | -4.3 |
| Added Value per equivalent labour year unit | 4.4 |

*Source: Instituto Nacional de Estatística, Contas Económicas da Agricultura (1980-2006)*

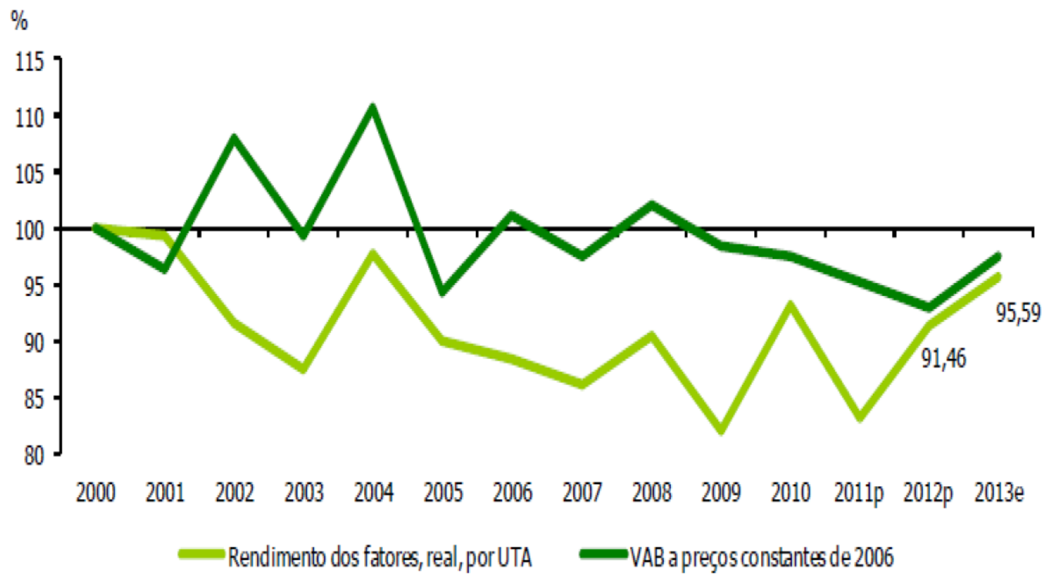


Figure 1.1. Real return of factors per annual working unit (UTA ) and Gross Added Value (VAB) at constant prices 2000- 2013 (2000=100%)

*Source: Instituto Nacional de Estatística, Destaque, Contas Económicas da Agricultura, 2013,1ª Estimativa*

This recent evolution trend is confirmed in figure 1.2 by the negative evolution (-7.2%) of the return per annual equivalent working unit compared in average terms of 2010/2012 relatively to 2000/2002. This return in Portugal was, at the time, already 27.9 percent below EU 27 average. Finally, this same figure is very useful to benchmark Portuguese values in absolute and relative terms with Polish values.

Return per AWU is 2.5 times higher in Poland than in Portugal and approximately the double of average EU values.

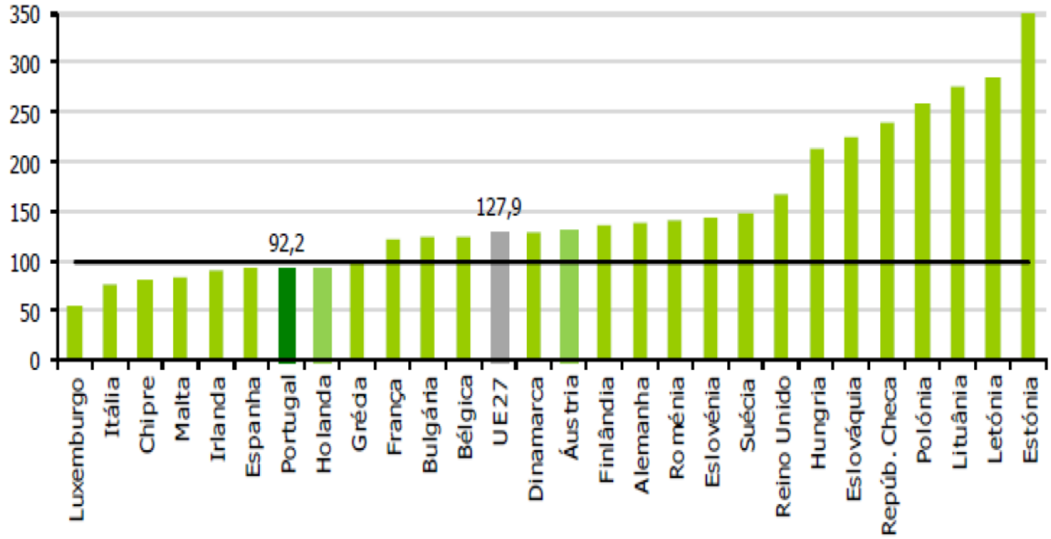


Figure 1.2. Percentage average return to annual working unit 2010/2012 in EU Member states (2000/2002=100%)

*Source: Instituto Nacional de Estatística, Destaque, Contas Económicas da Agricultura, 2013,1ª Estimativa*

### 1.4. Change in Portuguese Agriculture with CAP evolution and reform

In this section we try to relate the performance of Portuguese agriculture in aggregate terms with the evolution of CAP and its implementation in Portugal. Until recently, our view is that the contribution of CAP for the evolution of the sector has been decisive for structural adjustment without increasing total productivity and competitiveness of the sector.

The accession into the EEC and the adoption of CAP had a determinant influence on the evolution of Portuguese agriculture for the last three decades. This period was made of several sub-periods due to major events and changes in agricultural policy environment and CAP reforms. Implementation of CAP and successive reforms to agriculture in Portugal has been the main source of guidance of decisions of farmers and economic operators within the agricultural sector.

The negotiated and agreed strategy prior to membership (before 1986) relied on promoting investments, available from EEC structural funds, in order to prepare

Portuguese farmers to compete with the farmers of other European countries. Modernization of Portuguese agriculture through technological change would increase production and productivity, allowing for lower average costs and compete, in the medium run, with other EEC countries.

Very soon, before the end of the first stage of the transition period (1986-1990), Portuguese authorities realized that this would not be possible for two orders of reasons. Firstly, because other aspects besides production competences had been overlooked, namely marketing tools, institutional and associative know-how and governance, which were also needed. Secondly, because CAP adjustments, namely needed production control policies, including product price reductions, were larger than expected and would not be compatible with initial arrangements.

The renegotiations for the second stage (1991 -1997) tried to gain time and postpone the deadline (specific payments were set till 2003) for full adjustment of farmers of agricultural products involved but the pressure for integration from European Single Market adoption and from Mac Shary CAP reform definition and implementation ended up on negotiating compensations for full and immediate adjustment.

From then on CAP would not be neutral to Portuguese agriculture and farmers. To promote structural adjustment with stable EEC output prices was reasonable. But, to do it, with a policy setting of discouraging production and decreasing prices, and distortions in relative support favoring agricultural products without competitive advantages revealed to be totally inappropriate. A totally different logic substituted the initial objective of increasing productivity. Portugal and EEC needed different agricultural policies. But, in a short run view, to receive funds and maintain farmers' income, Portugal ended up "abandoning", for a long time, its agriculture.

In the first years of implementation of Mac Shary reform (1996) payments were set according to productivity levels of dryland and irrigated land, but it was necessary to maintain production options. This partial decoupling had several negative effects. Firstly, because payments were an important part of income and production levels with much lower prices were not sufficient to pay for total costs. The least the application of inputs the lower the costs of production of farming systems. This discouraged technological improvement and innovation in dryland crop agricultural systems and promoted extensification. Secondly, maintained farmers crop and livestock production orientation directed to non-competitive options. Thirdly, it did not promote the use of structural funds, the adoption of rural development programs and measures available to competitive and sustainable options.

To support farmer's income, CAP tied production options to historical levels of crops produced and supported. This has had perverse effects in the dynamics of agriculture. Income has been artificially supported through the revenue side with no incentive for change, particularly for larger farms benefitting from high total direct payment compensations. Agricultural enterprises restructured their systems and production equipment in response to measures of agricultural policy (direct payments), but not face the need for the future have to compete in European markets. Available structural funds were misdirected to production systems artificially supported and diverted from sectors and products with potential for competitive advantages. For too long CAP not only maintained and directed resources to stagnant sectors with low degree of innovation and discouraged technological change in those sectors but also hampered cultural diversification and conversion technology. The same applies to the development and effectiveness of implementation and effects of rural development policies and funds, including the agri-environmental measures.

But the response from farmers has continued to be very positive in terms of allocation of resources and production increase in cases of specific subsidies that allowed them more economic return. Two illustrative cases of the capacity and speed of their response are durum wheat and the breeding cow premium attached. The production of durum wheat was strongly increased when this crop, for a number of years in this period, benefited from a specific production premium. The cattle population has increased over the years and the sheep population has declined. The key explanation for this development was the existence of a subsidy, a premium per cow, which in relative terms is very favorable to cattle and has remained connected to production unlike sheep premium that was disconnected from the effective maintenance.

Full decoupling from production took too long and was needed a long time ago. For instance, recent developments suggest a new dynamic on land use and technological change towards modern implementation of permanent crops such as olive and fruit trees. The single payment scheme allowed for land to be shifted from traditional production options to these options maintaining direct payments. Investments in these Mediterranean options, well adapted and with potential competitive advantages can also benefit from structural funds to support farmer's investment. The same re-orientation had happened previously for vineyards. As a protected crop, with plantation rights, vineyards were previously supported with specific programs for investment and had annual return, during a period of years when domestic market consumption encouraged production, well above average returns.

Decoupling from production supports farmer's income and eliminates part of the negative effects of pricing policy in agriculture, since it promotes rational economic resource allocation among alternative uses. Indeed, without tying payments to production it is possible to make productive and technological adjustments and encourage innovation. It provides guidance for investments in research and development, experimentation, training, clustering of economic activities of the supply chain to overcome major bottlenecks and barriers for sector development and allows for social, environmental and economic rationality of measures of rural development with valuation of their social contribution at proper social and relative prices enabling sustainability of production systems.

However, some aspects of full decoupling and of today's policies still have unfavourable or unequitable effects. Firstly, income support in practice works as a rent, which might be an economic disincentive when it is relatively high for those who depend fundamentally on agriculture. Hence, it might not distort but discourage economic activity and unfavourable effects on rural development, particularly within regions having natural handicaps, where institutional and social-economic effects are even greater. These effects can be widespread if net margins are negative and no options are available as alternatives leading to abandonment.

### 1.5. Major reasons for reform and CAP Post-2013

As of today, the CAP continues to be a policy that maintains inequality of support among countries, regions and farmers. Since current payments have a base on historical rights, farmers, regions and countries receive support levels differently based on what they used to produce, of crops that were primarily supported by CAP and of values set for each country. For instance, it is known the historical bias of CAP towards supporting primarily non-Mediterranean productions, i.e., the productions of the countries that originally designed CAP. This distorts support among countries and producers.

Figure 1.3 illustrates the large variability of average payment per hectare for different EU member states. The average value is 264 euros per ha but varies from close to 550 to below 100 euros per ha. Portuguese average payment per hectare is 174 euros per hectare. Hence Portuguese farmers on average receive lower support from CAP than farmers of other EU countries. The same is true to Poland, with payment per hectare close to 200 euros, immediately before Portugal in the lower tail of the distribution.

The same applies among farmers. Payments per hectare also vary a lot depending on agricultural products produced and historical rights. Figure 1.4 presents Portuguese payment support per hectare by crop type. Values vary from more than 750 euros per hectare for rice lo less than 50 euros per hectare for flowers and horticulture. Besides rice, horto-industrial crops, milk and temporary crops are also supported above average. Fruits, sheep and vineyards are supported at levels per hectare below average values.

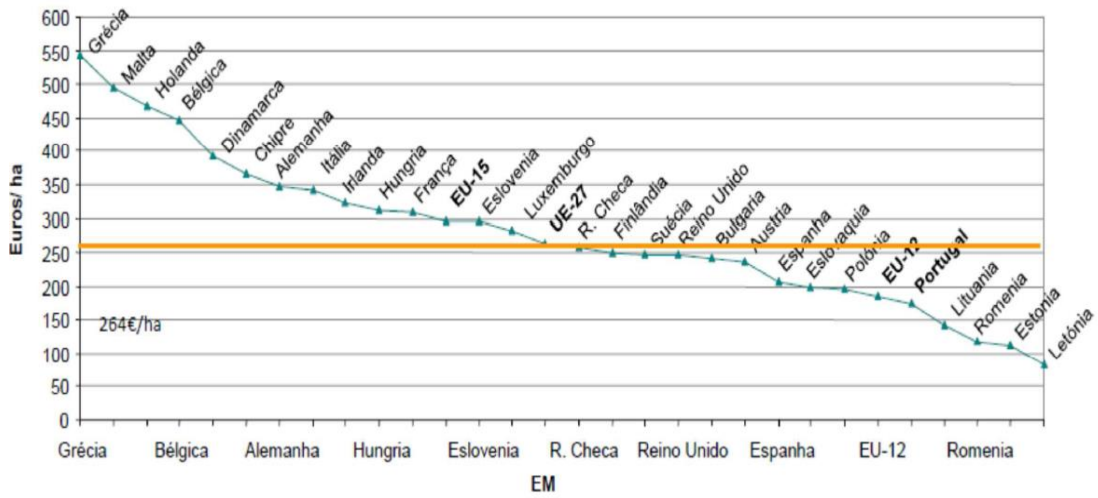


Figure 1.3. Average payment per hectare received per European Union Member state
*Source: Pinto (2011)*

This point was a major focus of reform for CAP post-2013. Payments based on historical rights are not rational in terms of agricultural policy. CAP should move towards a single payment per hectare regardless of production. Hence, this variability and the way to deal with it in the implementation of the single payment per hectare until 2020 established under CAP post-2013 is a key agricultural policy point to be addressed in the near-future by Portuguese authorities.

In addition, an important move of PAC post-2013 is to avoid abandonment and support active farmers. This is a form of dealing with one of full decoupling disadvantages without distorting crop orientation. In reality CAP goal is to support activity or work/labour of farmers and not only land. The link of single payment scheme to farmer's activity, despite the eco-conditionality and of other conservation practices (public goods), orientates the policy goals to people and introduces, in an indirect way, the topic of capping total payments.

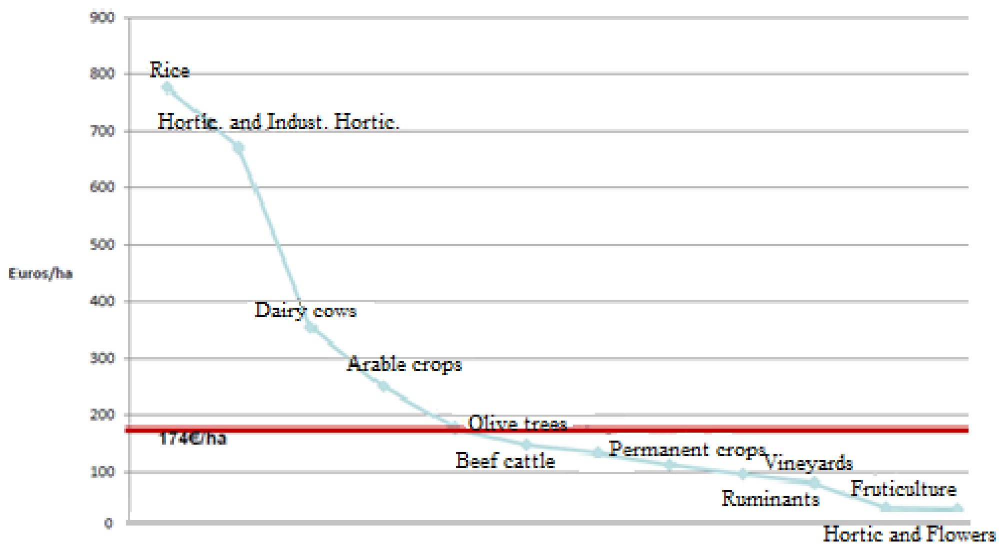


Figure 1.4. Average payment per hectare received per crop type in Portugal
*Source: Pinto (2011)*

Finally, it is needed a closer tie of farmers of agricultural systems and practices that deliver public goods with payment levels. This is a way to continue on the road of recognizing the value of public goods and eco-services offered by farmers in order to legitimate CAP due to its territorial and environmental contribution. CAP post-2013 also focuses on this aspect, pushing for a greener CAP, introducing a part of the payment, as a "greening" component.

For the Portuguese agriculture this is also most welcome. In fact, many of the traditional agricultural systems of Portuguese agriculture that have been used to preserve resources and conditions, namely soil, water, forest, biodiversity, landscape, and others, have an additional opportunity to remain sustainable. For instance, recognizing and valuing the environmental contribution of traditional agricultural systems of exploring the “Montado” of Alentejo region of Portugal (called “Dehesa” in Extremadura and Andaluzia regions of Spain), a mixed system of agri-forest use based on pasture, acorn from oak and cork trees and cork, taking in account other criteria besides the economic value of tradable and marketed resources and products, can contribute to their sustainability.

### 1.6. The CAP and the sustainable orientations for Portuguese farmers

CAP goals of viable food production, sustainable management of natural resources and balanced territorial development in Europe provides orientation for agriculture competitiveness and sustainability in the future.

Income support by CAP will continue to support European farmers, agricultural systems and activities, technologies and methods that contribute to rural development and deliver territorial and environmental public goods, including safety and quality of agro-food production.

Given this road for the future and the relevance and influence of CAP income support to Portuguese farmers, sustainability of Portuguese agriculture can be oriented through several guidelines and farming orientations. At least four types with particular characteristics can be thought of.

Structural incentives to investment will allow for agricultural companies and businesses to become more efficient in their production activities and more vertical and horizontal integrated in their supply chain as well as in international groups in order to maintain competitiveness of the European agriculture. Portuguese agri-business companies will benefit from this support and can specialize in competitive production sub-sectors moving along this orientation. Economic and investment groups and farmers suppliers of these groups or of well managed cooperatives will remain profitable, socially viable and environmentally responsible.

This orientation will allow for farmers with average land endowments, and some area under irrigation to remain competitive and be sustainable either by maintaining farming as a unique economic activity or a complement of their income resulting from other economic activities besides agriculture or even in agriculture in other farms. Direct payments may be an important complement to income of these farmers. However, their sustainability is not dependent on those payments.

The second orientation has to do with creating value and it is based on promoting differentiation and valuation of production. This value might have to do with different aspects, such as specific factors of natural resources and technical knowledge and its use in the systems, technology and production and marketing techniques that are to be promoted and developed. One possibility is to direct production to regional and local differentiated products. Attributes as quality certification, safety, public health, dietetic particularities, origin, local and regional location, methods of production and type of processing that can and should be related to characteristics of the environment, landscape, history, heritage, culture, gastronomy and tourism.

It is a second step to some farmers that may be able to move from the first orientation to this one. This orientation requires continuation of efforts of farmers to become agricultural entrepreneurs and move and integrate activities along the supply chain, including adaptation of field research and of production, processing and packaging technologies, priority to creation, adaptation and adoption of technical and business knowledge and innovation and innovative and entrepreneurial mindset and business capacity to profit from the possibility of adding value through characteristics which render specific features of the product.

A third orientation is focus on farming in order to promote economic feasibility through conversion technologies holdings and resize. This is a specialization based on efficiency and directed to build a land scale and utilization of traditional technologies and resource that has been happening. This type of farming combines the use of natural resources in an extensive form with low endowments of labour. It is based on a development of the family farming model production that needs to be efficient and become more market oriented in order to be sustainable. Training and technological capability is required to ensure efficiency and economic returns. This orientation combines income support of CAP, but is predominantly supported by economic returns from agricultural systems and productions.

This orientation can also be a development of well succeed farmers of the first orientation that besides using irrigation developed also the capability to buy or rent land that is used on crop and predominantly livestock, beef or sheep production, and that depend only from agriculture as economic activity.

The fourth and last orientation will be characteristic of marginal areas with low resources quality that cannot be sustained in an economic criteria basis. In these areas the orientation must be the production in association with the provision of a public service. In this case sufficient income is obtained through market receipts from production and from compensation for ecological services via CAP. In this orientation farmers use and preserve natural resources which have low productivity capacity at lower cost than society and compensation for farmers is assumed by society as social contribution to the maintenance of the natural resources. Landscape, cultural options, production guidance and technologies can be subject to planning in order to ensure and promote environmental goods.

Sustainable development of Portuguese agriculture and business will be based on agricultural farms that evolve following these orientations according to their technical-economic capacity and resource endowments.

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# 2. TRANSFORMATION TO SUSTAINABLE AGRICULTURE IN POLAND

*Józef Sawa*

**Key words:** *sustainability of agriculture, parity farm area, family income, parity income, degree of mechanization, intensity of organization*

## 2.1. Introduction

Effective agriculture is commonly based on intensive farming, using the industrial methods of production. The purpose of such agriculture is the maximization of the yield, production and profit. These objectives are realized, above all, through the application of the scientific and technical progress and systematic increase of the material and energetic expenses. Such farms apply the scientific and technical progress without any complex evaluation of its effects. The economic dynamics of European farms has changed completely during these recent years. The conventional correlation between quantity and profitability is not true anymore. Even though the food equilibrium is not yet reached at the world level, the aim of European farms is not any longer to increase the production but simply to be viable in the long term. In order to reach this objective, it is necessary to reduce the production costs and to increase the added value of the production. Therefore, the concept of high quality production was introduced a few years ago.

New concepts of rational management of agricultural production process include aspects such as "*Sustainable Agriculture"* = ecological + social + economic. In reality, the "*Sustainable Agriculture"* is a concept about our future, quality of food production and quality of human life. *"Sustainable Agriculture"* as part of *"Sustainable Development"* is more an ethical then a technical problem" - for developed country's above all.

*«Sustainable development»* is the concept about all human activities, our future and quality of human life in environment: ecological, social, economic. Because different groups of people have different needs (Figure 2.1), many definitions for this term are used.

In agriculture, as national economy basis for initiating "*Sustainable Agriculture*", are farms with Good Agricultural Practice (GAP), where integrated production in every branches of farm is applied. Every kind of production process is performed by applying scientific and technical progress, material as well as energetic expenses.

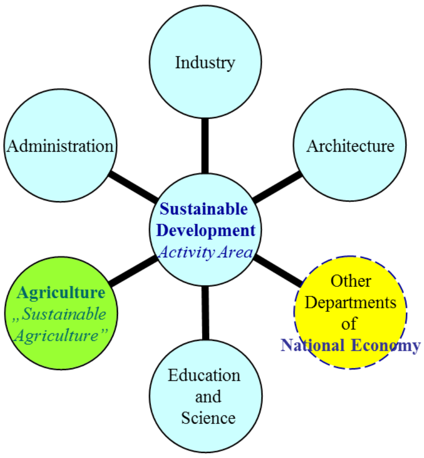


Figure 2.1. Sustainable Agriculture as part of the „Sustainable development"
*Source: own study*

Some authors define agricultural sustainability from various points of view, e.g. von Wiren-Lehr (2001) talks (Table 2.1) about the scale and scope of the implementation of sustainable processes in agricultural production.

Table 2.1. Basic dimensions and conforming levels of goal-oriented conceptual approaches to assess and implement sustainability in agriculture

| **Dimensions** | **Levels** |
|---|---|
| Normative | Ecological aspects<br>Economic aspects<br>Social aspects |
| Spatial | Local<br>Regional<br>National |
| Temporal | Long-term<br>Short-term |

*Source: von Wiren-Lehr (2001)*

Douglass (1984) identified three different views of sustainability. The first view was called 'sustainability as food sufficiency', within the constraints of profitability. The second view was 'sustainability as stewardship', defined in terms of controlling environmental damage. The third view was 'sustainability as community', defined in terms of maintaining or reconstructing economically and socially viable rural systems. Yunlong and Smit (1994) also distinguished three main perceptions of sustainability. The first is the ecological definition of sustainability, which focuses on biophysical processes and continued productivity of functioning ecosystems. The second is the economic definition of sustainability, which is mainly concerned with the long-term maintenance of the benefits of farming to agricultural producers. The third is the social definition, which addresses the continued satisfaction of basic human needs for food and shelter, as well as security, equity, freedom, education, employment and recreation.

Moreover, agriculture is no more considered as being only a production tool. Its socio-cultural and environmental role is taken into account more and more. Therefore, in Europe, we observed a kind of re-orientation of agriculture and new concepts of production and management have been introduced, such as integrated production, Good Agricultural Practice (GAP) and Sustainable Agriculture.

Those concepts should be differentiated in order to be understood well and in order to define their limits.

Integrated production plays a role on the scale of a field and it is a farming system that produces high quality food and other products by using natural resources and regulating mechanisms to replace polluting inputs and to secure sustainable farming. In this system, emphasis is placed on (IOBC/WPRS 2004):

- a holistic systems approach involving the entire farm as the basic unit,
- the central role of agro-ecosystems,
- balanced nutrient cycles, and
- the welfare of all species in animal husbandry.

The preservation and improvement of soil fertility, of a diversified environment and the observation of ethical and social criteria are essential components. Biological, technical and chemical methods are balanced carefully taking into account the protection of the environment, profitability and social requirements.

Only some production could be integrated without involving the entire farm and this is the basis for the implementation successively of GAP (Table 2.2) at the farm and Sustainable Agriculture Process in the region and the country.

Table 2.2. Sustainable Agriculture as a concept which should be implemented on the scale of a farms, region or the country

| Category of sustainability | Range of activities and possibilities (competence) | Place of performance |
|---|---|---|
| Integrated Production | Some branches of production on farm | Farm |
| Good Agricultural Practice | All branches of production on farm | Farm |
| Good Sustainable Agricultural Practice[1)] | All farm in region + regional agrarian policy[1)] | Region |
| Sustainable Agriculture | All farm in country + country government and UE agrarian policy | Country/UE |

1) Sustainability without engagement governments and regional institutions is not possible

The implementation of Good Agricultural Practices should be performed on the scale of the whole farm. It mainly concerns the organization and management of all the production process regarding the environmental protection at the farm level and its direct neighbourhood. Farming, according to GAP, requires broad agricultural knowledge and access to professional information. Those farms are less competitive than intensive ones and therefore they need financial support from the authorities. Sustainable Agriculture is a concept, which should be implemented on the scale of a region or a country– includes Integrated Production and Good Agricultural Practice concepts and also takes into consideration the socio-cultural and economic role of agriculture. The implementation of Sustainable Agriculture requires a political plan and choices of middle and long term.

An estimation of the structural changes of the Polish agriculture after the political changes in 1989 is presented.

## 2.2. Polish agriculture and agrarian policy in the period of structural change

Political and economic changes since 1989, as well as the perspective of joining the EU, are the main causes of the structural transformations of whole Poland, including Agriculture. The Common Agriculture Policy (CAP) and the fulfilling of its constraints and requirements was the main engine of the Polish Agriculture restructuration.

The complexity of this issue (Table 2.3) is emphasized by the fact that more than 1.6 million family farms still exist in Poland.

Table 2.3. Selected structural indicators of Polish Agriculture 2000-2010

| Specification | Units | Years | |
|---|---|---|---|
| | | **2000** | **2010** |
| Agricultural population | thous.<br>(%) | 7270<br>(19.0) | 5658<br>(14.8) |
| Number of holdings above the 1 ha AL | thous. | 1887 | 1562 |
| Area of agricultural land | mln ha | 17.8 | 16.6 |
| Area of arable land<br>- (% of cereals area) | mln ha<br>(%) | 13.7<br>(70) | 12.1<br>(73) |
| Livestock in terms of large unit (LU) | LU/100 ha | 40.5 | 42.4 |

*Source: GUS Statistical yearbook of agriculture 2012*

One considers a family farm an exploitation of more than one hectare of arable land (AL) (Figure 2.2). Those family farms cover about 90% of the arable land which reaches about 17 million hectares (for comparison, France 30 million hectares and Germany totalizes 17 million hectares) (Żurek, 2001).The agricultural employment rate is 24% of the active population and the general unemployment in Poland reaches at the moment about 15%. Owners of farms over 2 acres conversion are not unemployed persons. Only 50% of farms market their production. These considerations lead to the conclusion that half of the Polish farms are what we could call "social farms" (Szeptycki and Wójcicki 2004; GUS 2002).

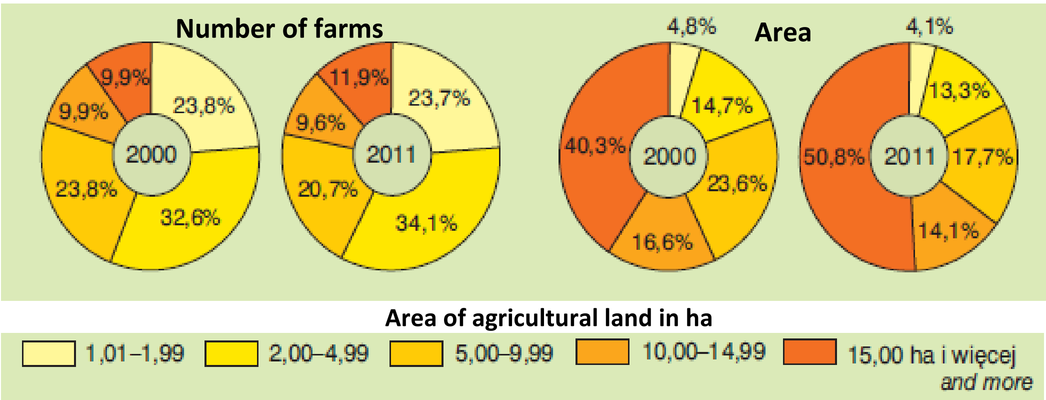


Figure 2.2. Structure of private farms exceeding 1 ha of agricultural land in years 2000 and 2011
*Source: GUS Statistical yearbook of agriculture 2012*

Fig. 2.2 shows the complexity of the Polish agriculture transformation. Moreover, this subject is undoubtedly a sensitive matter regarding the population directly involved. The adjustment of the production system to the new conditions is especially difficult for the family market farms. These farms have to change the organization of the agricultural production in order to ensure its effectiveness. Sometimes, they have to change its profile or even find other non-agricultural sources of income. If we strive for sustainable agricultural production, we must remember that Sustainable production process first of all refers to the *ecological sustainability* whose derivatives are: *social sustainability* and *economic sustainability*. Anyhow the aim of farmer work effect is: the bests' secure of their family life conditions and farm process durations. However, from a social point of view the measures of economic farm situation are important, e.g.: the level of agricultural production and the parity income in reference to other sectors of the national economy. It is also the some questions for conception of Sustainability Agriculture as sector of the National Economy.

The purpose of this paper is to present, based on an enquiry conducted to 26 family farms, the dynamics of changes of the organization and the level of production observed during the last 20 years.

**2.3. Methodological approaches for assessing agricultural sustainability**

The 26 Polish family farms have been followed between 1993 and 2013, but the main attention was given to the period of Polish accession to the EU, i.e., from 2003 (one year before accession) to 2010.The farms are situated in different regions of Poland. The selected farms were mixed type farms, which produce both plants and animals. The studies were carried out within the research projects realized by the Institute of Building, Mechanization and Electrification of Agriculture in Warsaw and the University of Life Sciences in Lublin with the cooperation of the researchers from the Agricultural Universities from Krakow, Poznan, Wroclaw and the Warmia-Mazury University of Olsztyn (KBN program: 50489/91.01; 5P06F-01216; NCBiR nr NR 120043 06/2009 (Wójcicki, 1993; 2000; 2009) and 3P06R 037 22 (Sawa, 2004)).

The farms have been purposefully selected with the help of the Provincial Agricultural Advisory Centre (PAAC). The purpose was to select family farms, which deliver their products on the market, and with a good potential of competitiveness. Independently of their size, the selected farms fulfilled the following criteria:

- more than 50 % of the man power is provided by the family,
- more than 50 % of the family income is provided by the farm activity,

- the production process is mechanized,
- the level of production is higher than the Polish average.

The evaluation of the activity of the selected farms is based on numerical data and information's given by the farmers themselves or collected from the farmer documents (bills, invoices…). The farm's production process was studied three times during the period of 20 years and an analysis of its changes was conducted. Changes concerning the intensity of production organization, the level of renewability of the organic matter, the material and energetic expenses and the level of production were studied. For the assessment of changes over the joining Polish EU structures and considering the fact that the selected farms in year 2010 included a large scale of size (from 8.6 to 115 ha AL), the farms were divided into 4 area categories: up to 20 ha AL, 20-50 ha AL, 50-80 ha AL and more than 80 ha AL.

**2.4. Definition of basic indexes**

Several system attributes believed to influence sustainability are identified and measurable indicators identified for each. A negative change in an individual indicator suggests that the system is unsustainable. Recognition of the need for quantification has motivated efforts to combine indicators into integrated quantitative measures. Lal et al. (1990) propose the following quantitative equation for measuring sustainability:

$$S = f(P, E, D, C, W, .....)t \qquad \dots (2.1)$$

where:

*S - sustainability,*
*P - agronomic productivity,*
*E - total energy input,*
*D - measure of soil degradation,*
*C - carbon efflux from soil and the biomass into the atmosphere,*
*W - water quality,*
*t - time.*

Another example is presented and proposed by Smith and McDonald (1998). Sustainable Agriculture is a concept which should be implemented on the scale of a region or a country. Sustainable Agriculture includes Integrated Production and Good Agricultural Practice concepts and also takes into consideration the socio-cultural and economic role of Agriculture. The implementation of Sustainable Agriculture requires a political plan and choices of middle and long term.

The present paper makes use of the following indexes which served in the estimation of the transformation of the agricultural production process :

- *theoretical parity area of farm (Q ha AL)* necessary for the farmer's family to obtain, comparably with the mean annual (+1 month) income per one worker in the budgetary sphere (for a given area) (Nietupski and Szelwicki, 1981),

$$Q\ ha\ AL = 13\ Imb*n/If \qquad ...\ (2.2)$$

where:

*Q ha AL – parity area of a farm (ha AL),*
*Imb – mean monthly income per one worker in the budgetary sphere (PLN),*
*If – annual income of an agricultural family (or a chosen category of income, e.g. the income of an enterprise) per ha AL in a given farm) in PLN/ ha AL,*
*n – the number of convertible family members employed in a farm.*

Measure of economic farm situation:

$$Q\ ha\ AL \leq actual\ area\ ha\ AL \qquad ...\ (2.3)$$

- *coefficient of intensity of production organization of farm* is a point evaluation (usually 200-600 points) of the agricultural production (both plant and animal) in a farm. Depending on the obtained effects in the farm and the level of material-energetic expenditures, 5 scales of evaluation are used. The studied farms were evaluated according to the $4^{th}$ scale (Kopeć, 1987).

- *coefficient of reproduction or degradation of the soil organic substance* (table 2.4) is a point index making it possible to determine the balance of the organic matter (taken from or submitted) in the soil. This index has positive or negative values (Kuś and Krasowicz, 2001).

Table 2.4. Soil organic matter balance 15 ha farm arable lends (t/ha AL)(Example)

| **Specification** *(Agricultural culture)* | **Repro-duction coe-fficient** | **Arable lands as %** | | **Arable lands as ha** | |
|---|---|---|---|---|---|
| | | **Cropp-ing pattern %** | **Results** ***column*** *2x3* | **Cropping pattern ha** | **Results** ***column*** *2x5* |
| *1* | *2* | *3* | *4* | *5* | *6* |
| Cereals and oil crops | - 0.53 | 68.50 | -36.3 | 10.27 | - 5.44 |
| Root crops and vegetables | - 1.40 | 19.20 | -26.9 | 2.88 | - 4.03 |
| Maize | - 1.15 | 1.90 | -2.18 | 0.28 | - 0.32 |
| Perennial crops -grass | + 0.95 | 9.40 | +18.4 | 1.42 | + 2.78 |
| Perennial papilionaceous | + 1.96 | 0 | 0 | 0 | 0 |
| Pulls crops | + 0.35 | 1.00 | +0.36 | 0.15 | + 0.05 |
| Summa: degradation by plants | x | 100.00 | - 46.62 | 15.00 | - 6.96 |
| Organic matter *degradation* by plants (t/ha) | x | x | - 0.46 | x | -0.46 *(as -6.96 : 15 ha)* |
| Manure fertilization (ton/ha) | + 0.07 | 8.0 | + 0.56 | 8.0 | + 0.56 |
| Straw incorporated to the soil (ton/ha) | + 0.18 | 0.5 | + 0.09 | 0.5 | + 0 .09 |
| Organic matter *reproduction from manure and straw* | x | x | + 0.65 | x | + 0.65 |
| Balance soil organic matter in farm (ton/ha) | | x | + 0.19 | x | + 0.19 |

*Source: own study, on basis: (Kuś and Krasowicz, 2001)*

- *level of the material and energetic expenses* expresses the level of expenditures; in kWh for the input of agricultural engine and in man-hours and index degree of work process mechanization on farm (Zaremba, 1985);

- *level of agricultural production* was given in relation to agricultural market net output expressed in cereal units (CU).

The three main indicators (table 2.5) of sustainable agriculture used in the paper are environmental, economic and social components.

Table 2.5. Category and indicators use for measure of Sustainable Agricultural process

| **Environmental elements**<br>(indicators)<br>**maintenance of the natural fertility of the soil and reduction of the natural environment degradation** | **Social elements**<br>(indicators)<br>**mechanization of labour processes, reducing the effort, securing the safety and comfort of life for agricultural producers** | **Economic elements**<br>(indicators)<br>**the level of agricultural production and the parity income in reference to other sections of the national economy** |
|---|---|---|
| Reproduction or degradation of the organic matter,<br>(satisfying index 0.4 – 1.5 tons/ha AL) | the estimation of hour man work, including the level of work inputs (hour/ha of arable land) and work equipment (kWh/man hour) 2000 hour man work/ worker/year or 36 000 MJ) | Agricultural market net output in cereal units (CU), over 55 CU/ha AL |
| | the degree of mechanization of the work process on farm:<br>$\frac{kWh \cdot 0{,}2}{kWh \cdot 0{,}2 + \text{man hours in year}}$<br>(satisfying index > 70%) | Standard area of farm in relation to the parity income (Q ha AL):<br>- family income<br>- enterprise income<br>The parity area of farms :<br>**Q ha AL ≤** actual area **ha AL** |

*Source: own study*

## 2.5. Sustainability of the agricultural production process in family farms

The economical and agricultural indexes show clearly that the selected farms differ from the average farm in Poland. This difference concerns the size of farms, which usually have about 8 ha of arable land (ha of AL); the level of employment (about 20 workers in conversion to 100 ha AL); and above all the level of material-energetic inputs (Szeptycki and Wójcicki, 2004; Kurek and Wójcicki, 2011).

This group of farms and especially those where the work of the family constitutes more than half of the labour expenditures and where the incomes are the basis of maintaining the farmer's family (family farms) arouses the greatest interest and presents good future prospects. Family farms have always had considerable independence and have always been connected to the market through the commercialization of their own production (for a part to the fresh local market and for a greater part to the agro-industry).

Observing the changes in the organization and level of agricultural production was considered purposeful, especially for this group of farms, which could be compared with the UE farms. The structural changes analysed in the selected farms, between 1993-2010 (table 2.6), are stigmatized by the increase of the area of ha AL (205 %) and the increase of the energetic inputs (127%). The increase of labour expenditure is about double, while in 2010 the expenditures of man labour (an hour of man labour = a man-hour) was only 51% of those in 1993. It should be emphasized that in the same time the employment also decreased from 12.4 in 1993 or 6.1 work man per 100 ha AL in year 2003 to 4.1 in year 2010.

However, the transformation of the agriculture has its negative consequences. Regarding the organization of the production process, the observed increase of production in year 2010 in agricultural market net output in cereal units (CU) from 42.6 in year 1993 to 69.1 CU/ha AL in year 2010, is accompanied by a reduction ( in the same time) of the animal stock of about 16% in year 2003 and 55% in year 2010, having as consequence that the stock slightly exceeds 1 LU/ha AL.

The changes also have their effect on the type of plant production, which is reflected by the 35% reduction of the intensity index of production organization. The type of crops undergoes changes in the selected farms, where about 70% comprise cereals and corn for fodder, which have replaced the fodder crops, especially mixtures of grasses and the papilionaceous (Sawa, 2004).

A reduced stock of animals and the change of the cropping pattern affected the possibilities of farms regarding the balance of soil organic matter. In the analysed period the farms practically had no possibilities of maintaining the level of organic matter on arable lands (coefficient of organic matter reproduction 0.38 in 1993 and 0.43 in 2003 to 0.27 ton per ha AL in year 2010).

This disadvantageous tendency goes against the basic rules of the Good Agricultural Practice.

All the enumerated changes in the sphere of increasing cultivated area, reducing the expenditures of labour per a unit of area, decreasing the production intensity and renewability of the soil organic matter only caused that the level of the agricultural market net output was maintained. In 2010 the level of this category of production expressed in Cereal Units/ha was 150% as compared to 1993 and 128% as year 2003.

Table 2.6. Characteristics of family farms evaluated in the year 1993, 2003 and 2010

| **Item** | **Units** | **Evaluated in the years** | | | **In 2010** |
|---|---|---|---|---|---|
| | | 2010 | 2003 | 1993 | 1993=100 |
| Number of evaluated farms | number | 26 | 26 | 26 | 100 |
| Agricultural land area on farm | ha AL | 55.9 | 42.4 | 27.2 | 205 |
| Animal stock | LU/ 100 ha of AL | 65 | 99 | 118 | 55 |
| Number of workers ( full time on farm) | number | 2.3 | 2.6 | 3.0 | 86 |
| Inputs of man hour work | man-h/ha of AL | 88 | 115 | 192 | 51 |
| Agricultural market net output in cereal units | CU/ha of AL | 69.1 | 56.5 | 42.6 | 162 |
| Soil organic matter balance | t/ha | 0.27 | 0.43 | 0.38 | 71 |
| Inputs of agricultural engine | KWh/ha of AL | 1899 | 1837 | 1548 | 127 |
| Intensity of the organization of production – total | points | 310 | 407 | 474 | 65 |

*Source: own study on basis Wójcicki (1993; 2009) and Sawa (2004)*

Table 2.7. Comparison of sustainability Indexes of the production process in family farms investigated in the year 2003 and 2010

| **Indexes of sustainability** | **Unit** | **Years** | |
|---|---|---|---|
| | | **2010** | **2003** |
| Environmental sustainability | | | |
| - Soil organic matter balance – total | tons/ha AL | 0.27 | 0.43 |
| - Intensity of the organization of production – total (Kopeć, 1985) | points | 310 | 407 |
| - Animal stock | LU/100 ha of AL | 65 | 99 |
| Economic sustainability | | | |
| - Agricultural market net output in cereal units (CU) | CU/ha AL | 69.1 | 56.5 |
| - Family income | PLN/ haAL | 1839 | 2647 |
| - Standard area of farm for parity income (Q ha AL): | ha AL | 45 | 23 |
| *actual use area* | ha *AL* | 55.9 | 42.4 |
| Social sustainability | | | |
| - Inputs of hour of man work | man-h/ha AL | 88 | 115 |
| - Inputs of hour of engine work | kWh/ha AL | 1899 | 1837 |
| | kWh/ 1 man | 21,5 | 15,9 |
| - Hour of man work in year | man-h/year | 2138 | 1875 |
| Gradation of mechanization of work process (Zaremba, 1985) | % | 79 | 66 |

*Source: own study on basis Kurek and Wójcicki (2011) and Sawa (2004)*

Sustainability Indexes (table 2.7) of the production process were worsening. On the other hand economic and social indicators are acceptable. Also standard indicator area of farm income for parity (Q ha AL) is generally good.

**2.6. Selected results as transformation coefficients in categories of family farms evaluated in the years 2003-2010**

Considering the fact that the selected farms included a large scale of size (from 8.6 to 115 ha AL), they have been divided into 4 group areas: up to 20 ha AL, 20-50 ha AL, 50-80 ha AL and more than 80 ha AL. The studied year of 2003 was considered as the basis of the analysis and the comparison of results.

Structural changes of the selected farms are presented in table 2.8, where some of the analysed agricultural-economic indexes are evaluated for the two examined periods. The accepted manner of conducting the analysis makes it possible to state that the farms in all the groups increased the area of the utilized land at the level of 32%. The increase of the area (ha AL) in the farms was connected with the reduction of the expenditures of man-power and the increase of the use of electric and internal combustion engines. The most visible changes took place in larger farms with an area between 20-80 ha AL.

All the studied groups of farms limited the level of intensity of production organization and also in this case this process was especially well visible in the farms of over 80 ha AL as farm use below 20 ha AL.

What should be emphasized is the decrease of the index of animal stock LU/100 ha AL in the farms larger than 80 ha AL as opposed to the smaller farms. On the other hand, it is a positive phenomenon that in the farms of 20-50 ha AL the level of the net market production (cereal units AL) increased by more 100% with simultaneous moderate (9%) drop of the index of intensity of production organization and stable of manpower expenditures (man-hours/ha AL). Such tendencies cannot be seen in the groups of farms use below 20 ha AL.

The negative phenomenon of those changes is the low capacity of all the groups of farms to maintain or increase the content of the organic matter in the soil, special on the farms with more than 80 ha AL. The deterioration of the economic situation of the study group farms (except for holdings above 80 ha) shows unfavourable indicator Standard area of farm income for parity (Q ha AL).

Table 2.8. Selected results as transformation coefficients in family farms evaluated in the years 2003-2010

| **Item** | **Unit** | **Area group of farms (ha AL)** as 2010 year basis | | | | **Total 2010** |
|---|---|---|---|---|---|---|
| | | 20 < | 20-50 | 50-80 | > 80 | |
| Number of evaluated farms<br>- 2010<br>- 2003 | | <br>5<br>6 | <br>7<br>15 | <br>9<br>3 | <br>5<br>2 | <br>26<br>26 |
| Agricultural land area<br>as 2003 = 100 | ha AL<br>% | 14.3<br>118 | 31.1<br>111 | 65.5<br>163 | 115.1<br>119 | 55.9<br>132 |
| Animal stock<br>as 2003 = 100 | LU/ 100 ha AL<br>% | 86<br>68 | 93<br>125 | 87<br>70 | 28<br>45 | 65<br>65 |
| Inputs of hour work<br>as 2003 = 100 | man-h/ha of AL<br>% | 371<br>144 | 170<br>100 | 78<br>60 | 32<br>61 | 88<br>80 |
| Inputs of agricultural engine,<br>as 2003 = 100 | kWh/ha of AL<br>% | 2426<br>115 | 1548<br>99 | 2888<br>123 | 627<br>41 | 1899<br>103 |
| Inputs of kWh on one man-hours,<br>as 2003 = 100 | kWh/1 man-hours<br>% | 6.5<br>80 | 9.1<br>100 | 36.7<br>200 | 19.4<br>66 | 21.5<br>124 |
| Agricultural market net output in cereal units, as 2003 = 100 | CU/ha of AL<br>% | 50.0<br>89 | 112.3<br>208 | 69.2<br>114 | 52.7<br>107 | 69.1<br>122 |
| Intensity of the organization of production – total,<br>as 2003 = 100 | points<br>% | 373<br>72 | 383<br>91 | 338<br>82 | 201<br>76 | 310<br>76 |
| Soil organic matter balance – total, as 2003 = 100 | *t/ha*<br>% | 0.73<br>77 | 0.33<br>82 | 0.27<br>53 | -0.26<br>173 | 0.27<br>62 |
| Standard area of farm for parity income (Q ha AL),<br>family income | ha AL<br>PLN/ha AL | 21.6<br>4380 | 28.9<br>3280 | 69.6<br>1358 | 47.0<br>1470 | 45.5<br>1839 |

*Source: own study on basis Kurek and Wójcicki (2011) and Sawa (2004)*

## 2.7. Conclusions

The analysis showed that the studied market family farms take an active part in the process of transformation, which also includes the Polish agriculture.

These activities are intended to increase the area of the farm but with a reduction of the intensity of production organization, which makes it possible to reduce the burdening of the workers.

Level of net market production (69.1 CU/ha AL), relative to the conditions of managing the farm is not so satisfactory. Therefore a serious economic problem is the low standard area of farm for parity income (Q ha AL) in farms utilizing less than 80 ha AL.

On the other hand, a serious „Sustainable" problem is the low activity of farms utilizing less than 20 ha AL or more than 80 ha AL production scale and economic limits. Problems for the second group of farms are limited to possibly high efficiency of manpower, regardless of the intensity of the production process or the biological-ecological aspects of management.

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## 3. ENERGY EFFICIENCY IN AGRICULTURE. SHOWCASE AND ALTERNATIVES FOR WHEAT PRODUCTION IN PORTUGAL

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***Key words***: *wheat, energy efficiency, greenhouse gas emissions, production costs*

### 3.1. Introduction

It is expected that energy consumption will increase significantly in the coming years, causing a major impact on the economy in general and necessarily in the agricultural sector. One of the EU target indicators for Europe is a "20% increase in energy efficiency" by 2020. According to the Energy Services Directive 2006/32/EC, there is a need for improved energy end-use efficiency in all energy consuming systems. In this Directive, energy efficiency is defined as the ratio between an output of performance, service, goods or energy, and an input of energy. But energy efficiency in agriculture can also be assumed as the reduction of primary energy consumption (PEC) necessary to obtain one unity of product at the farm gate level (GJ/t). This was the definition used in this study.

Energy use reduction can be achieved by reducing energy input. Improved energy efficiency, however, is only achieved, if energy input per unit yield is reduced. Therefore, improved energy efficiency can be achieved with either increased or decreased energy inputs depending on the input-output relationship. The reduction in energy consumption is also associated with technological change, improvements in organization and management systems, or improvement of the economic conditions in the sector.

Agricultural production relies very much on the use of energy from fossil resources. However, the agricultural sector accounts for 3.7% of the total energy use in the EU-27 (EEA, 2012), which may seem insignificant, but it should be stated that in many countries national statistics record as energy use in agriculture only the direct energy (inputs used during the cultivation period). Energy use for the production of input materials (indirect energy), such as fertilizers, pesticides, machines and buildings is recorded under the industrial sector. According with Woods et al. (2010) and Pelletier et al. (2011), 50 % and more of the total energy used in agriculture is related to the production of nitrogen fertilizers and other indirect energy uses. If both direct and indirect energies are considered in an agricultural production system, then it becomes clear that a significant amount of total energy is required for the production of agricultural products and that energy saving should also be considered in this sector, as in most energy consuming sectors (Balafoutis et al., 2013).

This chapter presents some results obtained in the KBBE.2011.4-04 project "Energy Efficiency in Agriculture - AGREE" supported by the 7$^{th}$ Framework Program. It gives an overview into energy use and energy efficiency in wheat production in various agro-climatic zones of Europe. Among cereals, wheat is the crop with the largest cultivated area in Europe. In 2008, the percentage share of the area occupied by common and durum wheat in the countries analysed in the AGREE project ranged from 2.4% in Portugal to 18.9% in Germany (Gołaszewski et al., 2012). The different production systems in different climates vary substantially in their energy use and energy saving potential. A showcase of conventional wheat production in Portugal, where in 2012 it was cultivated in 54,761 ha (INE, 2013), is presented and some production alternatives are analysed. The main objective was to analyse the effect in the economic results, energy consumption and environmental impacts of three wheat production systems alternatives: 1. no tillage cropping systems, 2. reduction of phosphorous application and 3. the use of supplemental irrigation.

### 3.2. Methodology

In the first part of this chapter, it is presented the data regarding the energy use and energy efficiency in wheat production systems of 7 European countries. Both direct and indirect energy associated with all kinds of inputs used to produce wheat were considered. An LCA-like approach has been chosen, but the activities have been restricted to the farm gate. Energy use and productivity have been established for wheat production and the volume of inputs has been included considering Primary Energy Consumption (PEC). The energy equivalents used to convert the physical data of the input into the energy data have been preferably drawn on the BioGrace database (www.biograce.net). Some conversion factors, however, are specific for each country. For example, the PEC of electricity, which depends on the national energy mix used to produce electricity. The energy indicators used were Direct Energy Inputs, Indirect Energy Inputs, Total Energy Inputs and Specific Input of Primary Energy (GJ/ha and GJ/t).

The Direct Energy Inputs include all the energy used directly in the production process, including electricity, diesel and natural gas. Indirect Energy Inputs includes energy used for the manufacturing of production inputs, including fertilizers, pesticides, farm machinery as well as seeding material. The indirect energy associated with the construction of farm machinery has been excluded from this study. The reason is that a large variety of farm machinery is used in the field operations, data on the energy associated with the construction of farm machinery is missing and finally, the indirect energy from machinery has only a limited potential to contribute to energy savings in agriculture. Used energy has been estimated by multiplying physical units of application (kg/ha or l/ha) with the parameters expressing the energy per physical unit (MJ/kg or MJ/L) to result in the energy used per hectare.

In the second part, it is presented a showcase focusing in the production of wheat in the Alentejo region, Southern Portugal. Alentejo is the largest agricultural region of Portugal, with a Mediterranean climate characterized by mild winters and dry and hot summers. Annual rainfall is between 400 to 600 mm, concentrated in autumn and winter. Daily average temperature is between 21 and 25 ºC, but maximum temperature can be higher than 40 ºC while minimum is frequently below zero during winter nights (Marques 1988). A typical farm of 250 hectares, with clay soils and a traditional crop farming system of dryland agriculture was chosen as the basic scenario.

The farm traditional production system is based in a four years crop rotation (sunflower – *durum* wheat 1 – green peas – *durum* wheat 2) established to achieve high production levels of cereals. Usually, cereal, namely *durum* wheat, because of specific subsidy policies, or other cash cereal crop, alternates with sunflower and peas.

***Durum wheat I and 2 -*** Soil conventional preparation is based in a deep plowing followed by two chisel passages. Durum wheat 1 installation is then prepared with chisel and disc harrowing followed by sowing (200 kg seeds/ha) and fertilization (300 kg/ha of N20:P20:K0). Usually a crop weed control operation takes place (0.02 kg/ha of Tribenuron-Methyl and 0.5 l/ha of Clodinafop + Cloquintocete) followed by a fertilization with 150 kg/ha (N 27%). Harvest is in July, with an average yield of 3 ton/ha of grain and 1.5 ton/ha of straw.

***Sunflower -*** Soil conventional preparation is similar to the one performed for wheat, consisting in a deep plowing, followed by two chisel passages during winter, and one before sunflower sowing, in March. Sowing density is 4 kg/ha of seeds (75 000 plants). Sunflower does not receive fertilization or herbicide treatments and it is harvested in August. Productivity is 850 kg/ha.

***Peas -*** Green peas sowing occurs in January, with 150 kg/ha, after harrowing and two chisel passages for soil preparation. As for sunflower, green peas require neither herbicides nor fertilization treatments. Harvest is also in July, with productivities of 1100 kg/ha.

**Farm machinery**

To perform the above described field operations the farm machinery consists in one 105 HP tractor, one 9 tons trailer, one disc harrow, one chisel, one drill with 25 lines, a fertiliser distributor, a straw baler, a rake and a precision seeder. All the machines and agricultural equipment's are stored in a 75 $m^2$ building. The farmer also rents an 85 HP tractor with a plough implement, a 1000 L sprayer, and a combine harvester. In the economic evaluation, the rate value was calculated based in the replacement value and life span of each machine or agricultural equipment. The life span considers the durability of the item, the time between its first and last use. In the case of the tractors it was considered a life span of 12 years, for the seeders 13 years and for the disc harrow, the chisel and the trailer it was considered a life span of 20 years.

**EU financial aids**

All farms receive, each year, an EU subsidy, the RPU ("*Single Payment Scheme"*). The value received is different for each farm and it is calculated based on the farm history of producing the specific crop, and it also takes in account the existence or not of animals. The national average value attributed for the year of the study was 174 euros/ha.

**Alternative option 1 – No tillage**

No tillage or direct seeding has been studied in Alentejo in technological and economic terms by Azevedo and Cary (1972), Basch (1989, 1991), Marques and Basch (2002), Rosado (2009), Carvalho and Lourenço (2013). This cropping system has being applied in wheat for several years in Portugal, by a small number of farmers, but it's a practice that has been increasing over the years as a sustainable and environmental friendly agricultural practice for wheat production. Diesel used for the machinery is one of the most important production factors contributing to direct energy use and greenhouse gas (GHG) emissions. Reduced tillage or no tillage had been identified as efficient measures to reduce energy input use in agricultural systems. These systems need less fuel associated with lower mechanization use, which reduces production costs and greenhouse gas emissions.

As an alternative option for the traditional farming system it was considered a no tillage system for all the crops, maintaining the same rotation.

***Durum wheat I -*** In the third week of October a weed control operation is performed using glyphosate (3 l/ha). Sowing is in November, using a direct drill seeder, with seed density of 200 kg/ha and fertilization level of 250 kg/ha (N 15: P 15: K 15). In late January there is a fertilization with 140 kg/ha (27% N). During February it takes place a crop weeding operation (0.02 kg/ha of Tribenuron-Methyl and 0.5 l/ha of Clodinafop + Cloquintocete). The harvest is in July, with the same average yield attained in the traditional farming system.

***Sunflower -*** In late February an herbicide (glyphosate) is applied. The sunflower sowing is in March, also with a direct precision seeder and a plant density of about 75,000 plants/ha. Harvest is performed in August.

***Durum wheat 2 -*** *Durum* wheat 2 ends crop farming rotation, and has exactly the same annual calendar and operations of *durum* wheat 1. The productivities are also similar to those of *durum* wheat 1.

**Farm machinery**

To perform the above described field operations the farm machinery consists in, (from the actual existent farm machinery): one 105 HP tractor, one 9 tons trailer, a fertiliser distributor, a straw baler. All machines and agricultural equipment are stored in a 75 $m^2$ building. The farmer would need to rent a direct drill seeder, and still rent a 1000 liters sprayer and a combine harvester.

**Financial aids**

In this option, besides the EU subsidies, there is a national aid from the PRODER national program. This aid is granted to farmers that do organic farming, integrated pest management, breed indigenous breeds, and no tillage systems. The program has specific rules and maximum amounts for the different crops and animal breeds.

**Alternative option 2 – Reduced $P_2O_5$**

Indirect energy use from fertilizers use contributes to 30 to 50 % of the total energy use in agriculture. Therefore, it is expected that all measures to improve fertilizers use efficiency contribute to great extent for energy use efficiency. Differential application according with soil fertility is an option that could contribute to this improvement.

Based on data obtained by experimental research (Marques da Silva 2012) a reduction of 30% on the application of phosphorous on wheat crops was analysed as an alternative option. Since in this rotation system the application of fertilisers is only in the wheat crops, I and II, this option only applies to the wheat and not to all crops of the rotation.

**Alternative option 3 – Supplemental Irrigation**

One of the limitations in wheat production, in the Portuguese conditions, is the lack of rainfall in the spring in most of the years. Therefore, the possibility of applying some irrigation water in the grain filling stage of the crop has proved to be very efficient in increasing wheat productivity. However, these require either the existence of an irrigation system used by the other crops of the rotation or an additional investment in acquiring an irrigation system. It is also necessary to consider the need for increasing fertilizer application and the additional costs of electricity and water required by the irrigation system.

## 3.3. Results and Discussion

### *3.3.1. Energy consumption of wheat production in Europe*

One of the indicators of energy efficiency is the energy intensity of the economy expressed in units of energy used per unit of Gross Domestic Product (GDP). According to the EUROSTAT, from 2000 to 2009 energy intensity of the EU economy continued to decline slightly from 0.187 toe/€ in 2000 to 0.165 toe/€ in 2009. The EU agricultural sector accounts for 11.0 million jobs, which represent 5.1% of persons employed in the economy. At the same time the gross value added (GVA) of combined agriculture, hunting and fisheries accounted for only 1.7% in 2010. Nevertheless, there is a significant variance in GVA across Member States. In Greece and Poland the percentage share of persons employed in agriculture is relatively high, 13.0% and 12.5%, respectively, so the resulting percentage share of agriculture in GVA is also relatively high, 3.3% and 3.5%. On the other hand, Germany accounts only for 1.4% of the total employment and the 0.9% share of the sector in the GVA. Portugal is in between, accounting with 7.7% of the total employment and the 2.4% share of the sector in the GVA.

According to the European energy statistics, the total final energy consumption (FEC) of the EU-27 countries amounted to 49,205 PJ in 2008. The FEC of the sector "agriculture/forestry" was 1.071 PJ, corresponding to 2.2 % of the total FEC in the EU (Table 3.1). However, the Eurostat data presented in Table 3.1 is not sufficient to describe the energy consumption of European agriculture since not all the energy required for the production of agricultural products is allocated to the "agriculture/forestry" sector in the Eurostat statistics. For example, FEC of fertilizer production is allocated to the "industry" sector (Gołaszewski et al., 2012).

Table 3.1. The total final energy consumption (FEC) and FEC of agriculture (*including forestry) for the years 1998 and 2008 according to the Eurostat data.

| Country | Total FEC in PJ | | FEC of agriculture* in PJ | | FEC of agriculture* in % of total FEC | |
|---|---|---|---|---|---|---|
| | 1998 | 2008 | 1998 | 2008 | 1998 | 2008 |
| EU-27 | 46 658 | 49 205 | 1 257 | 1 071 | 2.7 | 2.2 |
| Denmark | 630 | 649 | 31 | 29 | 5.0 | 4.5 |
| Finland | 1 005 | 1 083 | 30 | 35 | 3.0 | 3.2 |
| Germany | 9 428 | 9 386 | 114 | 42 | 1.2 | 0.4 |
| Greece | 761 | 890 | 45 | 46 | 6.0 | 5.1 |
| Netherlands | 2 082 | 2 139 | 157 | 132 | 7.5 | 6.2 |
| Poland | 2 526 | 2 606 | 198 | 152 | 7.8 | 5.8 |
| Portugal | 672 | 773 | 25 | 15 | 1.0 | 0.6 |

The main indirect energy inputs concerning crop production are related with the accumulated energy in fertilizers and pesticides. Total consumption of nitrogen, phosphorus and potassium in the EU has been estimated at an average of 91 kg per hectare. The estimated average consumption of nitrogen in the EU has stood at 65.2 kg/ha, ranging from 21.8 kg/ha in Portugal to 136.6 kg/ha in the Netherlands. Phosphorus consumption has an average value of 8 kg/ha in the EU, ranging from 5.2 kg/ha in Denmark to 13 kg/ha in Poland, and potassium-based fertilizers averaged at 17.8 kg/ha across the EU, ranging from 7.6 kg/ha in Portugal and 9.5 kg/ha in Greece to 28.8 kg/ha in Poland, 25.0 kg/ha in Germany, and 23.1 kg/ha in Finland. Also, total use of active ingredients of pesticides per hectare of utilized agricultural area varies to a great extent across the studied European countries under consideration, ranging from 0.7 kg in Finland to 4.8 kg in Portugal, and 5.6 kg in the Netherlands.

Table 3.2 shows the results obtained for wheat production in the countries under study. The highest yield in tons per hectare has been recorded for the Netherlands and Germany and the lowest in the southern countries – Greece and Portugal. The average energy input per hectare of wheat production varied greatly among the countries involved. Specific energy inputs vary from 2.1 to 4.3 GJ/t among countries. This range results from a relatively moderate variation in energy use per ha (from 12.0 to 19.9 GJ/ ha) and a relatively high variation in the yield level ranging from 3 to 8.7 t/ha.

Table 3.2. The energy input (PEC) in wheat production in different countries (adapted from Gołaszewski et al., 2012)

| **Country** | **Yield** | **Specific energy inputs** | |
|---|---|---|---|
| | t/ha | GJ/ha | GJ/t |
| Finland | 4.50 | 12.0 | 2.7 |
| Germany | 7.66 | 18.6 | 2.4 |
| Greece | 5.00 | 19.9 | 4.0 |
| Netherlands | 8.73 | 18.1 | 2.1 |
| Poland | 5.80 | 15.1 | 2.6 |
| Portugal | 3.00 | 12.9 | 4.3 |

There is a tendency for higher energy uses to be associated with higher yield which becomes clear in Figure 3.1.

The main energy input in wheat production is associated with the use of fertilizers as can be seen in Figure 3.2. The energy inputs required for the use of fertilizers ranged from 6.3 GJ/ha in Portugal to 11.2 GJ/ha in Germany. The second main energy input is diesel use for field operations. The other direct and indirect energy inputs have been to a great extent specific for geographical location of countries. In the Central and Northern EU countries Germany, the Netherlands, Poland and Finland the additional energy on wheat production has been associated with drying. Indirect energy use is a considerable part of total energy use in wheat production. It varies between 50% and 72% depending on the country. This indirect energy use is mostly associated with synthetic fertilizer use. Diesel and fertilisers are very important production factors contributing to energy use and greenhouse gas emissions (GHG). Therefore, all measures to improve the efficiency of fertilizer and diesel use will contribute to energy use efficiency to a great extent and reduction of environmental impacts.

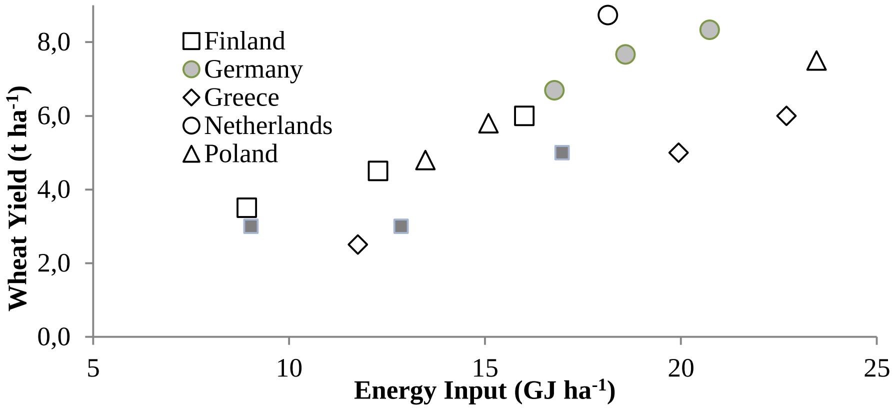


Figure 3.1. The relation of the total energy inputs in GJ/ha and yields in t/ha (Gołaszewski et al., 2012)

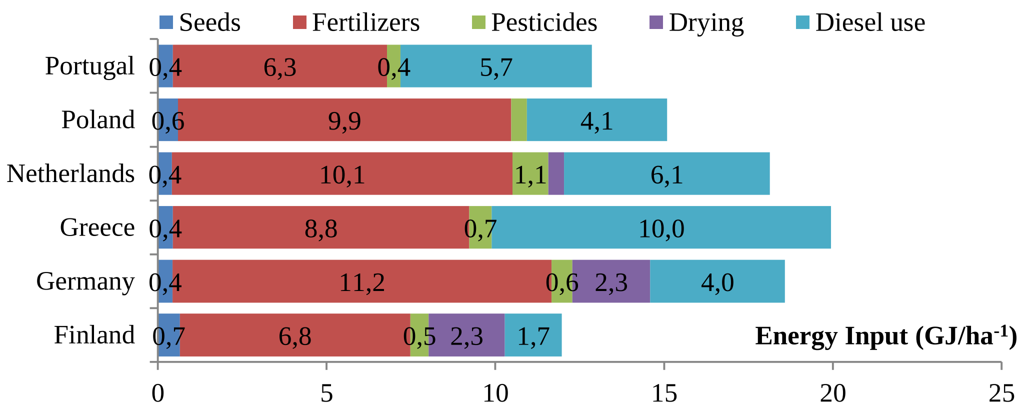


Figure 3.2. The structure of energy inputs in wheat production in GJ/ha (Gołaszewski et al., 2012)

### *3.3.2. Wheat production in Portugal. Showcase and alternatives*

Concerning the showcase for the wheat production in Portugal, Figure 3.3 shows the relative contribution of the different inputs in the total costs, GHG emissions ($CO_2$eq) and energy consumption for all the crops considered in the conventional production system of this farm, assumed as the basic scenario. It is clear that different inputs contribute in different percentages to the total costs, primary energy consumption and GHG emissions. This implies that small changes may induce only little costs but high impacts on energy use and GHG emissions. Also, we can observe that fertilizers and diesel are the most important concerning

GHG emissions and energy consumption. The relative high contribution of seeds for the total costs is explained by the fact that two of the crops do not require fertilization and pesticides.

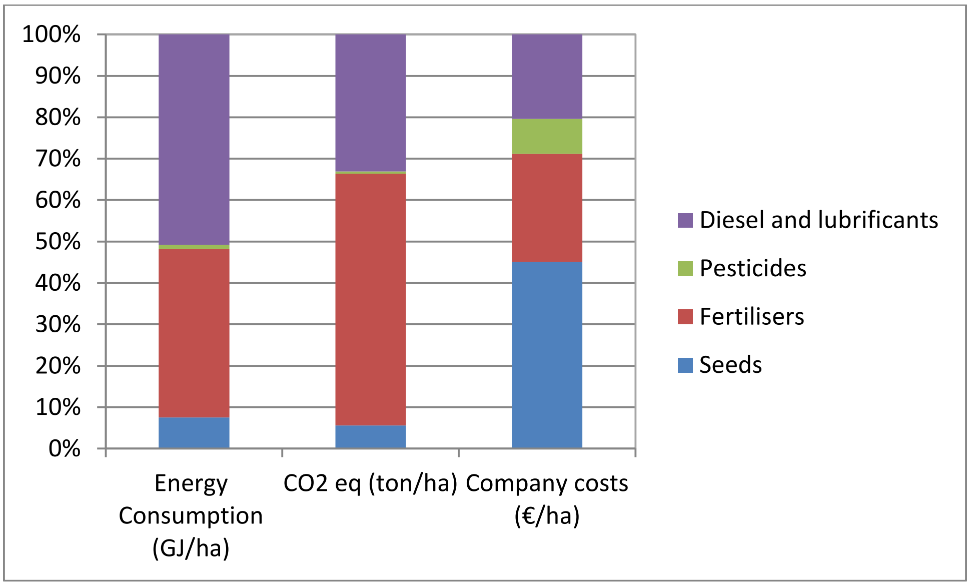


Figure 3.3. Relative contribution of different processing units and inputs in the crop rotation to economics, energy use and greenhouse gas emissions (GHG) for the basic scenario

Table 3.3 and Figure 3.3 present the costs, energy consumption and GHG emissions per hectare and considering all the crops of the rotation. In an overall analysis it can be stated that options 1 (no tillage) and 2 (fertilizer reduction) decrease costs, energy consumption and GHG emissions and the opposite occurs with option 3 (irrigation). In fact, production costs decrease about 10% with no tillage, 1% with less use of $P_2O_5$ and increased around 50% with the introduction of irrigation. The same is observed in energy consumption and GHG emissions.
No tillage allows reducing energy consumption for about 40%, fertiliser reduction reduces it around 2% and irrigation increases energy consumption for almost the double compared to the conventional system. For the $CO_2$eq emissions a decrease of 20% is obtained with no tillage, 2% with reduce fertiliser application and an increase of around 70% with irrigation. The decrease in the two first options is explained by less use of machinery/diesel and fertilisers and the increase in the

last one is due to the increase inputs of fertilisers and electricity for the irrigation system.

Table 3.3. Annual costs, PEC and GHG emissions with energy efficiency measures in the farm rotation

| **Specification** | **Annual Costs** | | **PEC** | | **GHG** | |
|---|---|---|---|---|---|---|
| | €/ha | % | MJ/ha | % | $CO_2$eq/ha | % |
| Conventional | 528.43 | 100.0 | 7171.26 | 100.0 | 535.97 | 100.0 |
| No Tillage | 482.90 | 91.4 | 4109.36 | 57.3 | 431.70 | 80.5 |
| Reduction $P_2O_5$ | 522.63 | 98.9 | 7045.01 | 98.2 | 527.06 | 98.3 |
| Irrigation | 770.25 | 145.8 | 13979.11 | 194.9 | 900.23 | 168.0 |

In Figure 3.3 it is also showed the impact of the different options on the farm profit. It is possible to see that all three options allow an increase of farm profit (43% with no tillage, 2% with less $P_2O_5$ and more than the double with the irrigation option). In the first two the increase is due to a decrease of the production costs and in the last one due to the increase of yield. Figures 3.4 and 3.5 allow a more detailed analysis for the wheat crop (produced in 125 ha of the showcase crop rotation), taking in account the wheat productivity in the different options. These figures show the costs, profits, energy consumption and $CO_2$eq emissions per hectare and per ton of wheat produced in the farm.

In Figure 3.4 it is shown the same tendency mentioned before considered all the rotation crops. Options 1 and 2 decrease costs, energy consumption and GHG emissions and the opposite occur with option 3. In fact, production costs decrease about 8% with no tillage, 2% with less use of $P_2O_5$ and increase around 66% with the introduction of irrigation. The same is observed in energy consumption and GHG emissions. No tillage allows reducing energy consumption for about 45%, fertiliser reduces around 3% the energy consumption and irrigation increases energy consumption for almost the double compared to the conventional system. For the $CO_2$eq emissions a decrease of 30% is obtained with no tillage, 2% with reduce fertiliser application and an increase of around 70% with irrigation. Finally, the profit per hectare, increases with no tillage (24 %) and with irrigation (approximately the double).

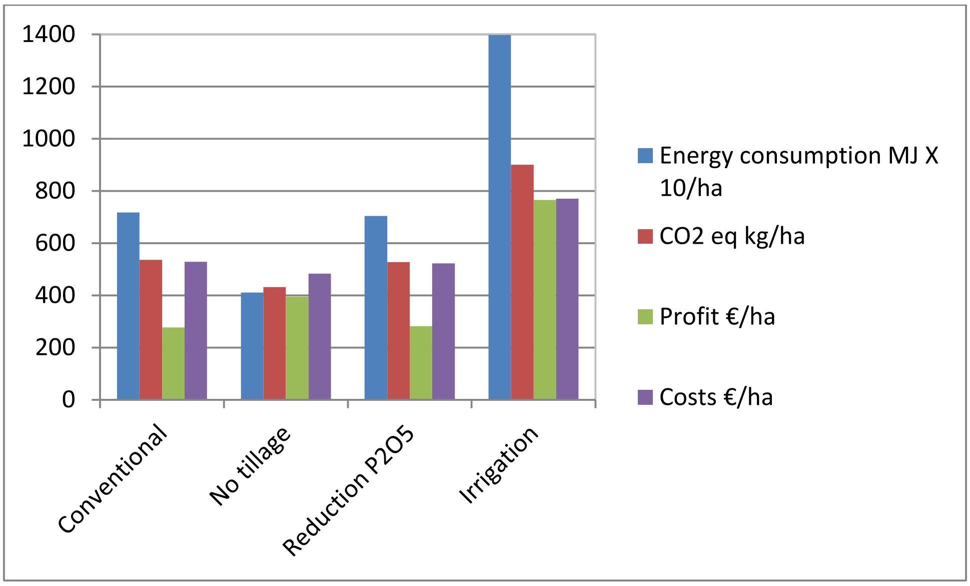


Figure 3.4. Impact of different energy saving measures on costs, profit, energy use and greenhouse gas emissions (GHG) per ha

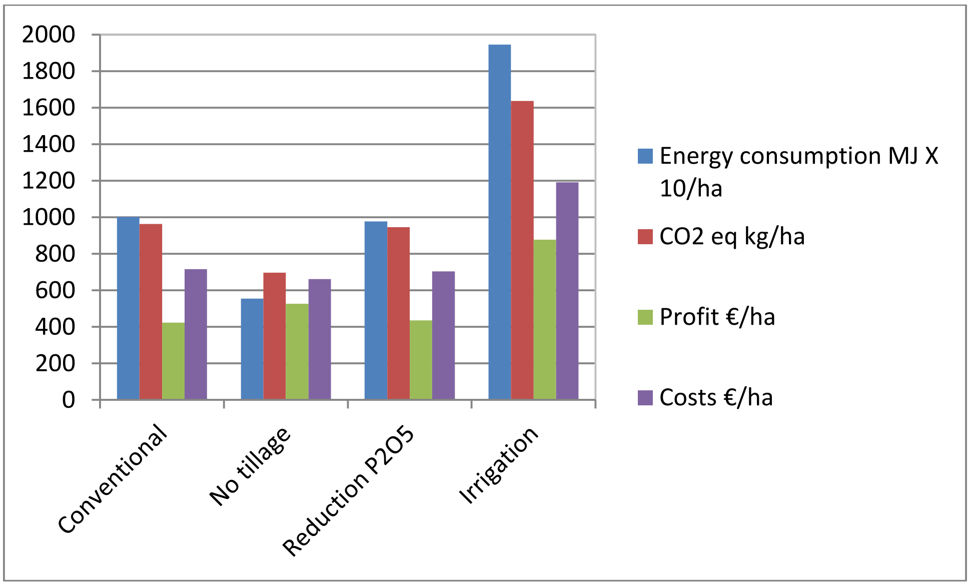


Figure 3.5. Impact of different energy saving measures on costs, profit, energy use and greenhouse gas emissions (GHG) per ha of wheat

Figure 3.6 presents a slightly different picture compared with the analysis performed by hectare. In fact, when considering the impact of the alternatives on costs, energy consumption and GHG emissions it is possible to say that the three options can contribute to an increase of the resources use efficiency (in different scales). Less energy is consumed, less GHG are emitted, and higher farm profit is obtained due to reduction of the production costs or either due to the increase of the productivity.

Analysing the variation of the costs per ton of wheat produced a reduction of around 8%, 2% and 17% was attained for option 1, 2 and 3 respectively. Concerning the energy consumption a reduction of 45%, 3% and 3% was found for option 1, 2 and 3 respectively. For the $CO_2$eq a reduction of 30%, 2% and 15% was attained. Profit increases for all the options, around 24% for no tillage, 3% reduced $P_2O_5$ and 4% for the irrigation. It is possible to see that the introduction of irrigation can contribute to the highest savings in the production costs. No tillage allows the higher savings in energy consumption and GHG emissions and the highest increase in farm profit. However, and in spite of the work done the wheat area in Portugal with no tillage is only approximately 4%, which indicates further research needs on costs not considered so far and adoption constraints.

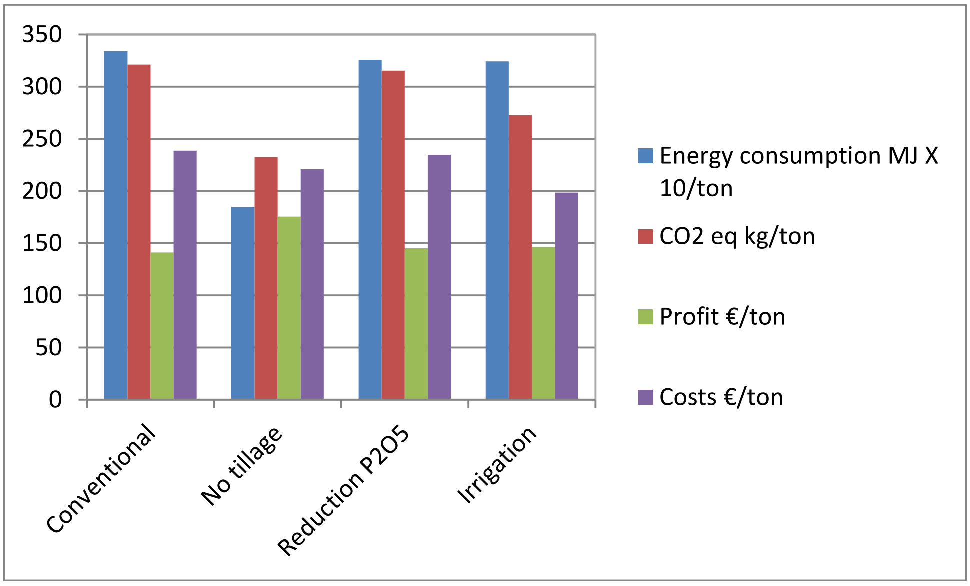


Figure 3.6. Impact of different energy saving measures on costs, profit, energy use and greenhouse gas emissions (GHG) per ton wheat

If we look to the specific energy inputs presented in Table 3.2, the wheat production in Portugal was the most energy consuming in comparison with the other countries. But that can be changed, if the production technology is adapted to our soil and climate conditions. In fact, as shown before energy consumption can be reduced to 5.6 GJ/ha and 1.85 GJ/t in different production systems, which could contribute to the sustainability of wheat production in Portugal. However, the knowledge must be transferred and farmers convinced of the advantages of these technologies. Also, more studies are in order to answer some remaining questions: Can this technology be used in all type of soils and climates?

### 3.4. Conclusions

The actual energy consumption of the European agriculture reported in the Eurostat statistics is underestimated. The efficiency of energy use in agricultural production is specific to the EU country and geographical location. The total and specific energy consumption varies substantially for all crops considered across Europe.

In the Portuguese case, the three analysed options showed a good potential to reduce inputs use in this farm, increasing the efficiency use of resources, thus contributing to the increase of the farm profit. The no tillage option seems to be the better one, with energy consumption and GHG reductions, and higher profit per ton of produced wheat. However, several factors interact in the production system and more research is needed in order to obtain more experimental data, in similar and different wheat production systems to allow a more conclusive analysis.

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## 4. SUSTAINABLE ENERGY IN SUSTAINABLE AGRICULTURE

*Janusz Gołaszewski, Fátima Baptista*

**Keywords:** *sustainable energy, sustainable agriculture, biorefinery, bioeconomy, circular economy*

### 4.1. Introduction

Sustainable energy means energy generation without detrimental impact to the environment and sustainable agriculture means pro-environmentally oriented farming and agriculture-based industry. Both activities, energy generation and agricultural production, tend to be mutually interrelated when associated with biomass production, biomass based products, and rural areas. Both activities generate relatively small part of gross value added of the national economies, i.e. for the EU-28: 3.1% and 1.7% by energy and agriculture sectors, respectively (European Union, 2013). At the same time, the energy and agriculture sectors are indispensable and crucial for the quality of mankind's life on the Earth.

In the last decades, the ongoing process of increased energy use is the hallmark of modern agricultural production, although the process is accompanied by a steady pace for increasing energy efficiency and reduction on energy intensity (Gołaszewski et al., 2013). The considerations on sustainability of energy use and agriculture presented in this paper involve two interrelated initial terms *more with less* and *ephemerization*. The first term is associated with the efficiency of natural resources and energy use. It was coined by Paul Hawken: "the future belongs to those who understand that doing more with less is compassionate, prosperous and enduring, and thus more intelligent, even competitive." (Hawken et al., 2008). The author of the second term is Richard Buckminster Fuller who claimed that the continuous progress in technological advancements enables to do „more and more with less and less until eventually you can do everything with nothing". According to this author, it is the reason that despite of growing human population and finite resources the standard of living will be increasing. At the first glance, "do something with nothing" is intriguing. However, there are some examples, which support this kind of process. Let us take into account the development of the information transfer system: historically, it was the messenger who delivered a message, then the post office system has been developed, and in the last decades thanks to technological advancements, information is transferred by invisible medium as invisible data. The same way of thinking may be adapted in the case of energy generation, especially in rural areas. For example, when a farm has a heat pump which is powered by electricity from the wind, water and/or solar sources and besides there is an opportunity to accumulate energy in own energy capacitors, the farm has energy for heating, cooling and electricity "from nothing". In both cases, the common applications are still limited because those technologies are far from economic, energy, and resource use efficiency.

Sustainable energy is supported by two pillars: increasing the share of energy from renewable sources and improving energy efficiency but only if these help to reduce greenhouse gases' emissions (Baptista et al., 2013; Gołaszewski et al., 2013; Meyer-Aurich et al., 2013). On the other side, sustainable agriculture supports a specific balance between many functions of agricultural production assuming a positive impact on environment quality. In the context of sustainable energy generation in rural areas, let us consider the three components which may add to sustainable agricultural production and energy autonomy of rural areas throughout, let us say: Energy Autonomous Regions (EAR). First, the energy will be generated from local energy resources, including waste/residual biomass conversion to energy in the closed loop of matter and energy circulation. Second, it will be built as the distributed energy system based on energy (co/poly) generation facilities combined in a smart grid. And third, the biomass will be converted efficiently to food, feed, non-food and energy products in (agro)biorefinery installations. The biorefinery will be a new quality in agriculture and at the same time an important element of the future market – bioeconomy and in a broader context – circular economy.

Building sustainable energy generation in rural areas ought to be seen as a process with some determinants. The energy generation from local energy resources should be scattered in scalable energy units (e.g. a farm, group of farms, village, commune, group of communes, etc.). EAR are going to be energy self-sufficient and energy will be generated with zero emissions. The long-term target is to power agricultural production and agricultural industry with a universal energy carrier, i.e. electricity. It will start a kind of „re-electrification" of rural areas. All of those determinants should be considered from the prosumer-oriented point of view, which means that securing energy self-sufficiency of each energy unit is the superior goal of sustainable energy generation and eventual surplus production will be sold.

In this review article the two hypotheses: 1) sustainable development needs sustainable energy, and 2) sustainable energy needs sustainable agriculture, are developed. Eventually, some scenarios for sustainability of energy and agriculture are considered.

### 4.2. Distributed prosumer energy generation and circular economy

Distributed prosumer energy generation means a system of local energy generation and consumption. The system is particularly suitable for development in rural areas. The system is based on distributed micro and small[1] scale energy generation installations integrated in the intelligent energy network. Such energy system may form a component of the energy network and at the same time a component of the local economy focused on building energy autonomy and rational use of natural resources, including biomass. The system operation is based on combination of different energy generation sources, complementary to one another offering the effect of synergy. The system is scaled starting with small installations at households through larger installations at agricultural farms and public utility facilities. Energy co-generators of diversified capacity with the real time energy monitoring system are integral components of the system. In case of rural areas, agro-energy complexes of that type at the level of the commune or county may form local energy centres that in addition to energy generation and distribution also balance the local energy potential and scope of renewable energy utilization, including environmental analyses. Scattered prosumer energy generation should be a consistent component of local economic activity based on rational use of natural resources in the system of closed circulation of the matter and energy – the circular economy.

As opposed to the industrial economy, circular economy means restorative/regenerative economy in which materials circulate within the closed circuit of the matter in two flows of processing (United Nations, 2012; Meyer-Aurich et al., 2013; Stahel, 1982, 2010; Stahel and Ready, 1976). The first concerns the so-called biological nutrients/materials and the second the technical nutrients/materials. The difference between those two components is that biological material is a component of the looped biosphere processes such as photosynthesis, restoration of the humus in the soil, circulation of energy, elementary carbon, nitrogen and oxygen, evaporation and numerous other biological phenomena involved in the life on the Earth. This means that the organic matter possesses the potential for restoration of the biosphere. On the other

[1] under 50 kW and 500 kW for micro and small energy generation units, respectively

hand, the technical materials maintaining high quality circulate outside biosphere and their circulation is supplied with energy from renewable sources.
Table 4.1 presents the important discriminants of the circular economy compared to conventional – linear economy. In the conventional economy, production is the resultant of the production volume increase that is accompanied by exhaustion of natural resources and continual disposal of waste.

Table 4.1. Discriminants of circular economy (agriculture, industry) in comparison with the linear economy characteristics

<table>
<tr><th>Conventional economy – linear</th><th>Circular agriculture (restorative/regenerative)</th><th>Circular economy (restorative/regenerative)</th></tr>
<tr><td>– Industrial production is separated from land, land is separated from labor, economic value is separated from moral value.<br>– Business is organized to make money.<br>– Finance and development in industrial economy are equivalent to earning money.</td><td>– Agricultural production in the sustainable system allows regenerating the soil and restoring its natural state and moreover, limiting or resignation from use of chemicals influences health values of agricultural raw materials.<br>– Biodiversity is retained.<br>– Local community benefits because waste from agricultural production return to the environment limiting production costs and reducing pollution and thanks to healthy agricultural products influence human health.</td><td>– Production success and profitability depend on the possibility of integration with or cyclic restoring of the ecosystem in its means of production and distribution assuming that the energy is generated from renewable sources.<br>– Business and environment restoration are unity – they are elements of the same economic process.<br>– Market competition of entities results from the ability of those entities to increase/restore the natural environment resources and not on exhausting them.</td></tr>
<tr><td></td><td colspan="2">– Circular economy (including agriculture and industry) restore the capital in all areas of their activities: financial, manufacturing, natural and social.<br>– Economic effectiveness analysis considers not only strictly production outcomes but also the environmental and social outcomes (holistic systemic approach).<br>– Economic effectiveness improvement involves waste free production and as a consequence savings on costs as well as maintaining and restoring the environment.</td></tr>
</table>

That model of the economy may develop only thanks to the availability of raw material (the resources of which are limited) for production of goods and energy (mainly from fossil resources). In the context of circular economy, agriculture, first of all, restores its production resources and maintains biodiversity while thanks to the more effective use of the means of production it limits the consumption of agricultural chemicals and increases health supporting values of agricultural raw materials. Resignation from linearity is the base of circular economy. This means integration of the production process with environment protection within the closed economic system within which waste is the raw material for other products („waste is food”). In such a model of the economy environment pollution is minimized.

**4.3. Political conditions of sustainable rural development – strategic documents**

The motivation for this paper is provided by the current European Union policy expressed in the following documents:

- The EU Framework Programme for Research and Innovation for the years 2014-2020 „Horizon 2020” aiming at economic development through support for scientific research and implementation of innovations in numerous sectors of the economy.
- Roadmap to a Resource Efficient Europe. 20 September 2011.
- A Roadmap for moving to a competitive low carbon economy in 2050. 8 March 2011.
- Our life insurance, our natural capital: an EU biodiversity strategy to 2020. 20 April 2012.
- European Parliament resolution on innovating for sustainable growth: a bioeconomy for Europe. 2 July 2013.

In the light of the referenced strategic documents, manufacturing products and providing services in the way assuring restitution of the natural environment will be a fundamental component of sustainable economic development in the EU. In that context, the issues of rational natural resources, including air, water, and soil management are becoming of key importance. Those resources determine the potential of agricultural and forest production, natural environment and the entire landscape structures functioning, which in turn translates into human life standard and quality. In the systemic approach to sustainable natural resources

management, industry based on raw materials of natural origin will be an important innovation economy development impulse. It is estimated that products obtained from renewable biological resources (biomass) will gradually replace the products manufactured today from fossil fuels creating a new market of bioprocesses and hence the new market of bio-products and services – the bioeconomy (European Union, 2011, 2013). According to the OECD data, by 2030, the biological raw material conversion processes will form 25% of the global market. Bio-products, including among others biofuels and bioenergy will be produced in a certain sequence of processes in the so-called biorefineries (refineries of biological raw material) (Gołaszewski et al., 2012). Biorefinery may be an installation constructed for the purpose of processing the raw material of specified chemical platform or it may be built based on the existing enterprises dealing with processing of both primary biomass (dedicated production of agriculture, forestry and aquaculture) and secondary biomass (waste from agricultural, forestry and aquaculture production) as well as tertiary biomass (wastewaters, industrial and municipal waste). In the European Union, an increasing number of economic sectors initiate the process of conversion/expansion of production to biological resources and production of bio-products. Enterprises from the sectors dealing with production of chemicals, cellulose and paper, sugar and starch as well as technology sectors, mainly biotechnology and process as well as industrial engineering dominate.
According to the principles of the natural environment sustainable development, the biorefinery becomes a logical alternative to satisfy human needs for both the food and market products manufactured today from fossil fuels, including fuels and energy. Moreover, the biorefinery with closed organic matter circuit, supplied with energy from renewable sources (including own processes) represents the supreme goals of bioeconomy focused on continual restoration of natural resources of the environment and preventing climate change.

Currently, there are no commercial comprehensive biorefinery technologies in the world. On the other hand, there are numerous pilot biorefineries that already today produce hundreds of bio-products, including biofuels and bioenergy. Scandinavian countries (transformation of paper industry), USA, Canada (timber and paper industry) and Brazil (bioethanol) are particular leaders in that field. Biomass represents the sole alternative for gaining independence from fossil fuels. However, today the fundamental problem results from the fact that simple biomass conversion processes leading directly to obtaining biofuels and bioenergy (e.g. maze silage fermentation, combustion of forest biomass, etc.) are unprofitable and without subsidies they are unable to compete with cheaper products obtained from fossil fuels. Profitability of biorefinery is built by the chain of many bio-products ending in energy generation from the residual biorefinery waste considered in the context of the entire biorefinery life cycle as well as individual processes and bio-products. The environment-supporting dimension of that approach is strengthened further by the fact that energy necessary for biorefinery processes is generated from renewable sources only and in integration with the local intelligent energy system. This means that changes in the context of bioeconomy must apply the systemic approach, starting from biological raw material production/obtaining processes safe to the environment, through the economically effective processes of multiproduct processing down to own energy security within the locally integrated system using local energy sources that cover the process needs, the local community demand and as the outcome offering renewal of the environmental resources (the organic matter of the soil, quality of waters). That approach guarantees zero-emission, minimizing environment pollution and consequent regeneration of the natural environment resources.

Areas with domination of agricultural production as well as forest and widely understood water resources available are particularly predestined for development of the approach of that type. In the context of rational use of resources, areas with high share of marginal soils of low productivity may also be of large importance in production of biofuels and bioenergy.

### 4.4. Concept of sustainable energy generation in sustainable agriculture

Close interaction of managerial competencies with the development of technology focused on rational use of natural resources will be the aim of actions in building sustainable prosumer energy generation. It is assumed that as the outcome, it will stimulate sustainable economic development, mainly in the rural areas. Competitive industry of biomass (bioeconomy), rational management of local natural resources (soil, water, forests, lakes) and energy generation from renewable sources integrated within the local economic system, autonomous and energy efficient to a large extent, with minimized emissions and environment pollutions, regenerating the natural resources in the natural way will be the base. In particular, such activity aims at:

- implementation of the new technological solutions in production and conversion of raw materials and agricultural waste, including the use of biological progress through application of molecular methods and genetic engineering in cultivation of new plants suitable for cultivation under unfavourable environmental conditions offering increased photosynthetic productivity and yields, more effective use of water and available mineral components as well as increase in effectiveness of outlays on agricultural production;

- implementation of new biomass processing processes, including those in the area of biofuels and bioenergy replacing energy and fuels manufactured from fossil resources;
- establishment of new business entities dealing with production and services at all stages of the value chain: raw material production, logistics, processing, distribution of bio-products, waste use for energy generation and other;
- development of new business models of integration of entities participating in building the value chain as well as expanding the production offer of agricultural, forest and aquatic biomass processing enterprises based on the economic-energetic-environmental balances, including trade-off and trade-up relations.

The key importance for development of energy technologies in the context of the local economic system in rural areas integrating prosumption of numerous biorefinery products, will have scientific-research accomplishments and implementation of the results of research associated with the following areas.

1. Raw material – production, acquisition, valorization, logistics. It is created by the biological raw material production and processing infrastructure built based on the best technologies and best environmental practices available. The raw materials base will consist mainly of the (i) biomass from dedicated agricultural, forestry and aquaculture production competing with neither production for food purposes (e.g. development of marginal lands, areas of former aggregates' mining, degraded lands/reservoirs) nor traditional processing of forest resources (paper and timber industry), (ii) waste from production and agricultural-food industry, (iii) local wastewaters and municipal waste. It is assumed that the infrastructure of that type should secure introduction of new biological sources of raw material, their adaptation to unfavourable environmental conditions and precise technical support to all production stages.

2. Biorefinery processes, including generation of bioenergy and production of biofuels. It is created by the biorefinery processes engineering infrastructure allowing development of innovative technical processes for manufacture of new products, including biofuels and bioenergy using, among others, white biotechnology employing microorganisms and enzymes and blue biotechnology focused on processes of aquatic biomass conversion in biorefinery processes in the industrial processes.
3. Energy generation. The infrastructure will consist of installations supplying biorefinery processes integrated with local systems of energy generation from renewable sources and local power infrastructure (smart-grid). The processes of biological raw material production, conversion processes, structures and buildings as well as energy generation installations will be balanced and analyzed from the perspective of energy efficiency. Local prosumption of energy and other biorefinery products as well as building energy autonomy at the level of biorefinery installation and the nearest environment as concerns influence of the agro-energy complex of that type – biorefinery, is assumed.
4. Market analyses and technology transfer. The infrastructure in that respect will be to a large extent of IT nature focused on modelling and optimization of operation. It covers the central system of monitoring and analysis in the "cloud" for production, energy generation, economic and environmental processes. Development of business models for new enterprises starting up their activities in the area of biorefinery processes and business models for already existing enterprises expanding their production by new processes leading to new products will be an important component in that area.

### 4.5. Solution scenarios – model agro-energy complexes

1. Model agro-energy complex with the potential of biomass production/obtaining and the biorefinery processing adjusted to the specific production conditions of the region. Such facility is working in the closed matter and energy circulation cycle including energy production system (integration of various renewable energy sources) for the needs of biorefinery processes and of the local community included in the intelligent energy network. Types of biorefineries:
   - lignocellulose biorefinery installation. It can be assumed that besides the dedicated production all lignocellulose wastes, including cereal straw from production of cereals and oil plants will be the feedstock for the biorefinery.

Moreover, the biorefinery will use thermochemical conversion reactors. The entire plant should be complemented by IT infrastructure for monitoring the processes and analysis “in the cloud” of production, energy generation, economic and environmental processes, including integration of data from different processes,

– oil biorefinery for processing raw material bio-products from oilseed plants, including production of biofuels,
– sugar biorefinery processing raw materials from cereals and root crops, including plants possessing health supporting values (i.e. old wheat),
– other biorefineries considering the specificity of regional production and biomass source.

2. Agricultural farm with developed animal production and/or agricultural industry sectors. The installation of agricultural biogas plant with the capacity adjusted to the volume of waste will be the central component of agro-energy complex infrastructure. Biogas plant will produce energy in cogeneration and heat will be used for securing production in farm buildings while power surplus will be connected to the local power micro-grid. Innovative environmental technologies for alternative use of biogas plant waste for bio-fertilizers production will be the integral part of the biogas plant. The post-fermentation mass will be separated into the solid and the liquid fractions. The solid fraction will be processed to biochar or other biodegradable soil improvements while nutritive components (nitrogen, phosphorus and other) will be recovered from the liquid fraction on bio-filter. The remaining purified water may be returned to the process. Biochar is a commercial product with wide possibilities of application. Given the long period of biodegradation in the soil, it has a potential to improve fertility of soils by means of better water retention and restitution of organic matter (soil humus). In the context of waste disposal at the local level (village, commune, county), the biogas plant may be of centralized character or it can be a component of biorefinery (Gołaszewski, 2011).
3. Public utility facilities in rural areas (territorial government buildings, schools, health centers). The activities should involve implementation of new energy generation and energy efficiency improvement technologies. Components of the system will be (i) micro co-generation of energy from renewable sources, (ii) micro wind power plants, micro-photovoltaic and photo-thermal systems, (iii) CHP units supplied with unconventional fuels, (iv) energy conditioning and

storage systems and systems for standardization of parameters of the power from micro-sources transmitted to the grid, (v) equipment and IT systems for energy evaluation at the level of individual units and Energy Autonomous Regions, and (vi) systems of forecasting and profiling the activities of entities focused on production of energy and energy raw materials.

## 4.6. Conclusions

The presented integrated production-energy system for rural areas integrates biorefinery processes within agro-energy complexes for production of biological raw material for numerous bio-products and energy generation from local renewable sources assuming restitution of the natural environment resources, low emissions and minimizing other environment pollutions. The presented scenarios are encompassed within the frameworks of the future market bioeconomy in which the share of services and products resulting from use of innovative biotechnological processes and energy generation will be significant. Areas with large resources of agricultural, forest and water management raw materials as well as those focused on environment-supportive activities, including bioconversion to biofuels and bioenergy, are particularly predisposed for actions in the area of rational use of natural resources and bioeconomy in the circular system. Mutually linked, sustainable development of local energy generation and agriculture will be the determinant of bioeconomy development.

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## 5. PERSPECTIVE OF A SUSTAINABLE AGRICULTURAL MECHANIZATION STRATEGY IN THE ALENTEJO REGION

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**Keywords:** *agricultural mechanization, innovation, conservation agriculture, precision farming technology*

### 5.1. Introduction

Agricultural mechanization and engineering, have been identified as one of the greatest achievements of the 20th century. To prepare a hectare of land, effective field capacity changed from 25 days to 4 hours, comparing a man working with a hoe to one operating a 35 hp tractor (Briosa, 1984). From 2000 to 2010 the utilized agricultural area in Alentejo decreased by 5%, but it still represents 40 % of the Portuguese territory (Eurostat, 2012). A social and economic study according to the agricultural census (INE, 2011) shows coexistence of small farms in the north and larger farms in the south, of Portugal in the Alentejo region. The number of people working in agriculture has dropped by one third but it still represents 13.5 % of the economically active population. Half of the agricultural holdings are less than 2 ha, but farms with 50 ha or more represent 58 % of the total arable land and 2 % of all agricultural holdings. The average size of this 2% is 142 hectares, 12 times higher than the national average. In the same period of 1999 to 2009, there was a 10% increase in mechanization equipment and the number of new tractors.

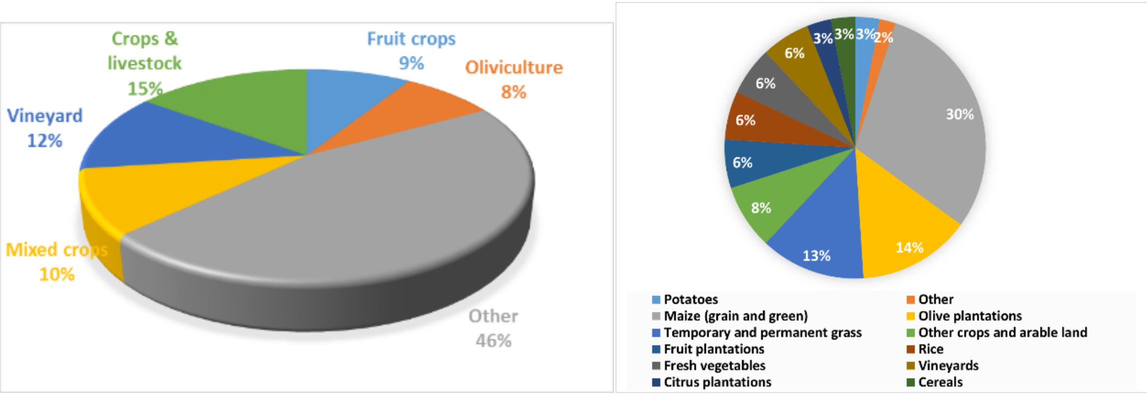


Figure 5.1. Percentage of the number of holdings by main type of farming (left) and that of irrigated area by type of crops (right), Portugal, (Eurostat, 2012)

The Portuguese farmer profile, is that of a 63 year old male who has only completed the 1st cycle of basic education and only has practical agricultural training working, at the farm. Regional key numbers demonstrate that in Alentejo, the average age of managers is 12 years younger than the national average, and about 40% have higher education, half of them with specific qualification in agricultural sciences. These profile differences may have a greater or lesser influence on facilitating understanding and acceptance of new technologies by both farmers and machine operators. In Alentejo, the gross added value of agricultural activity was 9.3%, in 2010, and represented 10.9% of the total employment in the region. An agro-engineering overview (Figure 5.1) shows the number of holdings by main type of farming in Portugal in 2010. With the exception of farms classified as "Various crops and livestock combined" under farm type (14.7 %), holdings specialized in vineyards are the most common in Portugal and an important percentage of rain fed crops are included in 46% of “Other crops” (Eurostat, 2012). In terms of the type of crops, the crops with the largest share of irrigation water in Portugal were maize grain and fodder. In Alentejo, comparing 2013 to 2010, as well as other irrigated crops, the area of maize production increased from 3.558 ha to for the current 5.925 ha, mainly because of the recent and increasing irrigated perimeter of Alqueva (ANPROMIS, 2014).

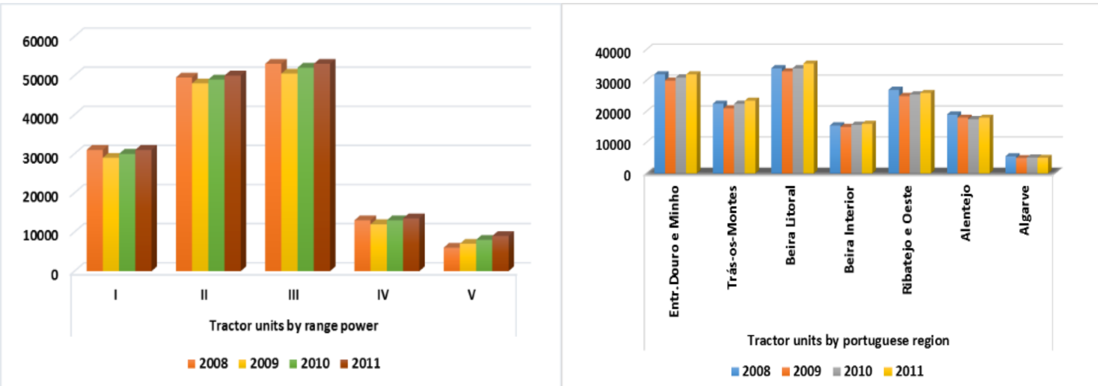


Figure 5.2. Distribution of tractors by engine power (class I – 35hp; class II- 35 to 50hp; class III – 50 to 80hp; class IV – 80 – 100; class V- >100hp) (left) and region (right) in the period of 2008-2011 (DGADR, 2014)

Considering the current status of agricultural mechanization in Portugal, the total number of tractors per region and the evolution of the number of tractors, by power range, in the period from 2008 to 2011 is presented in Figure 5.2 (DGADR 2014). Despite being the 5th region in terms of the number of tractors, with an average of 1 tractor per 100 ha, the Alentejo region has a high concentration of medium and high power range engines, 80-100 and over 100 hp.

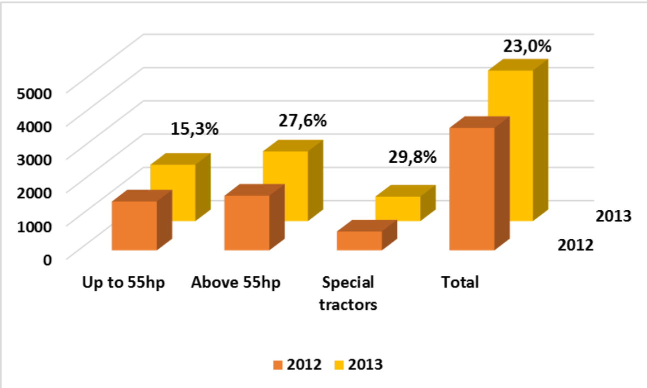


Figure 5.3. Percentage of registrations of new tractors from January to November by engine power category in the period of 2012/13 (ACAP, 2013)

According to the same source, in 2012 there was an increase of 2.58% in the number of motorized units, with the introduction of subsidized green diesel. In 2012/13, registration of new tractors from January to November, by engine power range, for classes ranging from 40 to 100 hp, accounted for 62.3% of the total registrations. The registrations for classes up to 40 hp accounted for about 21.5% and those for classes over 100 hp accounted for 16,2% (ACAP, 2013), Figure 5.3.

## 5.2. Key constraints to crop production

Some natural and economic constraints to crop management and production can be identified: Mediterranean soil and climate conditions, energy and fuel cost requirements, and, land and landscape approach. Alentejo has a Köppen-Geijer Csa climate and is characterized by hot dry summers and cold wet winters. Due to basic soil properties, climatic and weather conditions and land use and management, the status of soils varies both temporally and spatially. Unfortunately, conventional tillage systems have altered the physical properties of the soil, contributing to chemical and biological changes, reducing pH and soil organic matter, and thus affecting soil fertility, trafficability and workability. 70.2% of the Portuguese soils have medium cation exchange capacity and less than 1% of organic matter and 82.9% have a pH of less than 5.5 (Table 5.1). In what concerns farm fuel requirements, in 2012, from a national total of 141,731 farmers registered in agricultural diesel subvention and a total of 232,909,159.5 litres of fuel required, 11,509 were farmers from Alentejo, representing a total of 49,741,125.1 litres of fuel for 21,281 tractors, harvester machines and fixed engines used by irrigating systems (DGADR, 2014). Considering the continued rise in the global price of diesel since 2009, with a slight decrease in 2012 (USDA 2014), the official price of common diesel per litre in Portugal is 1 to 2 cents higher than the European union average of 1.39€/l (EEP 2014)) and that represents an important production cost, especially in irrigated crops. Also, with regard to energy costs, since 2006, with the suspension of aid payment for green electricity by the Portuguese State, which used to pay 40% of the electricity costs of farmers, with an amount of 20 million Euros per year, for nearly 28,000 farmers, the percentage of the cost of electricity can currently amount to 30% of the total cost of irrigation.

Another key constraint is land and landscape: the need for a closer relationship. The Europe 2020 strategy is about providing growth that is smart and sustainable, with a decisive move towards a low-carbon economy and respect for biodiversity and is targeted at minimizing waste and improving public perception of smart farming and thus optimizing input factors.

Table 5.1. Percentage of soil with high, medium and low values of cation exchange capacity (c.e.c), organic matter (o.m) and pH (Almeida, 1989).

| | **C.E.C.** (meq+/100g) | **O.M.** (%) | **pH** |
|---|---|---|---|
| **High** | 4.2 (>20) | 27.5 (>2) | 11.8 (>6.5) |
| **Medium** | 70.2 (10-20) | 2.2 (1-2) | 5.3 (5.5-6.5) |
| **low** | 25.2 (<10) | 70.4 (<1) | 82.9 (<5.5) |

Unfortunately, because of the exceptions, it is not always put into practice, particularly because of the professional profile of some older farmers and reduced competitiveness of some production factors, as described above.

### 5.3. A sustainable agricultural mechanization strategy

The holistic nature of sustainable agriculture is the concept that profit must be made over the long term, through stewardship of our land, air and water and implementing a quality life for farmers and their communities (UNESCO, 2014). So, any perspective of a sustainable agricultural mechanization strategy must take into consideration these aspects and if in the recent past the use of inputs such as fertilizers has been made rationally, according to the needs of the crop and the availability of land, the truth is that the application of this concept has been often theoretical, considering the ability of farm machinery. So, the joining of the two concepts of conservation agriculture and precision agriculture may suggest a strategy for sustainable smart farming. Lower labour requirement, less energy consumption and lower machinery costs, as well as other economic and environmental benefits, are associated with no-till farming, compared to conventional tillage systems and other types of conservation tillage (Uri, 2000, Tabatabaeefar et al., 2009). Compared with conventional tillage, fuel consumption and therefore total energy savings per hectare are 10% with reduced tillage and 32% with no-tillage, due to fewer mechanical operations and greater working capacity of the machines (Borin et al., 1997). With regard to the environment, adoption of no-tillage systems contributes towards reduction of soil erosion, increased crop residue retention and greater soil organic matter content. High technology in farm machinery, now available in low power ranges, such as *Tier 4A emission standard* with Selective Catalytic Reduction (SCR), Continuously Variable Transmissions (CVT), Isobus interface and virtual terminal, tire pressure control systems, low ground pressure tires or rubber tracks, strip-till solutions and no till seeders with active down force control and tramlines control system, variable rate sprayers and spreaders enhance the concept of conservation agriculture with more environmental and friendly machines. Site specific soil and crop management, also known as precision farming, is the smart concept, which implies the concept of using information regarding variability in site and climatic characteristics to manage specific sites within a field with best practices. Independent of the area or the crop, it is possible to manage spatial variability through quantity or quality. The process itself consists of 4 stages: data collection, data processing, data management and interpretation and finally application of the prescribed rates. Remote sensing, crop yield and mapping, guidance systems, GPS/GIS software and variable rate technology are nowadays available and built into farm machinery, allowing agronomists and farmers to manage crops according to demand. Automation systems and robotics may be the next step.

**5.4. Some case studies**

Since the 1980s different soil tillage systems have been used for the major cereal crops cultivated in Portugal, such as grain cereals, pasture, forage, sunflower and irrigated maize. In addition, the direct drilling option also represents cost and time savings because under irrigation two crops per year become possible, in Mediterranean regions. Except for sunflower the results show no yield reduction compared with direct seeding (Carvalho and Basch, 1994). Appropriate operation of the tractor engine and gearbox speeds; correct management of ballast and tire inflation pressure and adequate regulation of tillage implements can result in significant energetic efficiency. Because tillage operations in conventional farming systems are very power demanding and require significant energy input, sustainability requires a strictly-controlled management of resources and evident fuel consumption savings. In 2008 the University of Évora developed a data acquisition system to optimize agricultural tractor performance (Serrano et al., 2008). The time of fertilizing autumn/winter crops, in regions with Mediterranean climate and heavy textured soils, is often affected by poor trafficability conditions caused by precipitation, (Conceição and Mendes, 2008). Thus, the aim was to assess the viability of an alternative form of distributing fertilizers, aside from using a regular agricultural tractor. To this end an All Terrain Vehicle (ATV), equipped with a centrifugal pendulum fertilizer spreader was used for distribution of fertilizers. The obtained results make it possible to conclude that the use of an ATV, constitutes a credible alternative in situations of very poor soil trafficability. ATVs' costs are equivalent to those of a set of low pressure tires. They have a smaller coverage area per passage, and better mass and trafficability characteristics, compared to farm tractors.

They present a practical alternative, both due to verified lower soil resistance to penetration as well as absence of crop damage in their passage. Pernas et al. (2007) in a comparative study of the centrifugal distribution of fertilizer with and without a GPS in a 14 ha field, found that driving with a GPS increases the area where the correct rate of fertilizer is applied from 83.1% to 94.3%, thus reducing the percentage of overlaps and gaps from 10.5% to 1.9%. Monitoring maize harvest with a grain yield monitor on a combine harvester, has made it possible to expeditiously evaluate and build the respective maps of spatial variability in crop yield, in a total area of 281 ha, so that fertilization can be applied in an environmentally friendly manner in the following years (Marques da Silva 2006) (Figure 5.4).

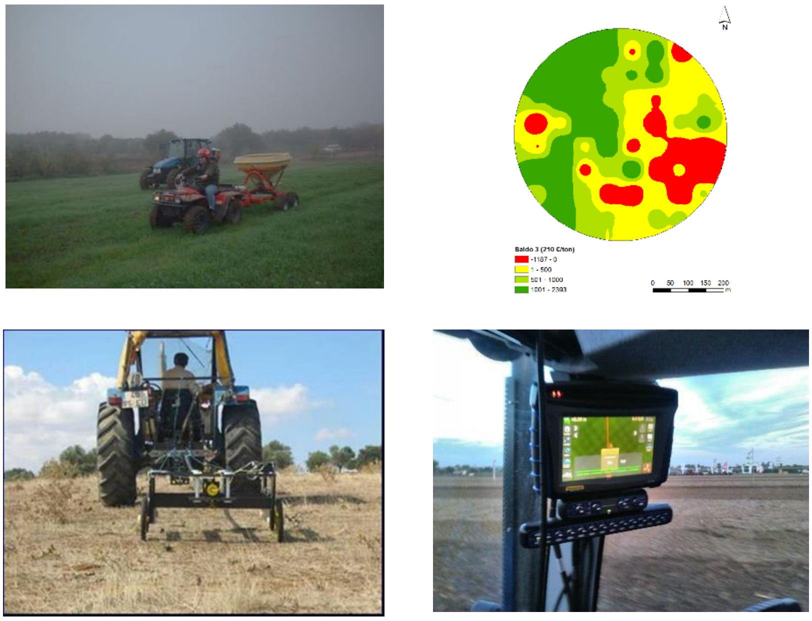

Figure 5.4. The use of an ATV, Yield mapping, tractors data management and guidance systems operations are some examples of the implementation of sustainable smart strategies of mechanization

Also in winemaking, the georeferenciation of plots and the analysis of quantitative and qualitative parameters in pre-harvest grapes have made it possible to define harvest dates and select grape batches for different wines (Conceição et al., 2003). With regard to importance of precision agriculture system in permanent pastures, Serrano et al. (2006) demonstrated a new technology for application of variable spreading and the importance of differentiated fertilizer management, particularly at the level of phosphorus application, Conceição et al. (2013) studying the spatial variability of seed depth placement of maize under no tillage in Alentejo, concluded that seed depth placement was significantly affected by soil moisture content and had a significant impact on mean emergence time and percentage of emerged plants, suggesting the need for improvement in controlling the seeders' sowing depth mechanism.

## 5.6. Conclusions

The main purpose of this analysis was to discuss a possible strategy for sustainable use of agricultural mechanization in the Alentejo region, considering its social, business and cultural practices, as well as some limiting constraints. Considering several case studies in recent years, the combination of the concepts of conservation agriculture and precision agriculture may suggest a strategy for sustainable smart farming. Alentejo has certain strengths that support the growth of the agricultural sector: there are institutes and university departments that work at the forefront of this field, carrying out research that is vital to agriculture and related technologies, as well as innovative and dynamic farmers and a farm machinery market with innovative solutions compatible with sustainable concepts and precision farming technologies. Nevertheless, it is important to have a regulatory framework that better supports innovation and provides for increased investment in R&D, allowing faster and more widespread adoption of best practices and innovation across farming systems and farmers.

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# 6. TEST OF TECHNICAL EFFICIENCY OF SPRAYERS FOR THE ENVIRONMENT PROTECTION

*Stanisław Parafiniuk*

**Keywords:** *spray inspection, nozzles, testing device for nozzles*

## 6.1. Introduction

Increasing requirements on food production and a constantly developed conception of balanced agriculture caused that agricultural production processes are burdened with a wide range of duties, which should be fulfilled while using plant protection products. One of such requirements is a necessity to apply pesticides with the use of certified equipment. Equipment that is already in use should be periodically checked, at least every 3 years. These regulations are valid almost in all European countries. Periodic tests are carried out in sprayer control stations. General tests and tests of sprayer liquid systems are carried out using visual and functional methods. The most essential elements of the sprayer, which decide about the quality and efficiency of a spraying procedure are nozzles. Nozzles installed on the field beam of the sprayer can be checked in respect to their outflow intensity and the regularity of the stream fall of atomized liquid. However, the results of these tests are not comparable if done with different evaluation methods. Most European countries prefer a method of testing the stream of atomized liquid done with the use of groove tables. Electronic groove tables with 100 mm groove spacing are preferred with the help of which the coefficient of variation (CV) is counted. If the value of this coefficient is not higher than 10%, stream distribution of atomized liquid is considered correct. So called manual groove tables with 50 mm spacing and 3 m wide, for which 15% of measuring cylinders should not show deviation higher than ±15 %, are acceptable. In Belgium, France, Greece, England a method of the outflow intensity from nozzles is used. In Poland, Portugal and Sweden both testing methods are accepted. Countries like Denmark, Latvia, Romania have not decided yet how to perform these tests (Godyń et al., 2013). The important element of doing these tests is common availability of devices, which enables to evaluate a technical state of equipment for pesticide application. In Poland, the Act of 18 December 2003 (Dz. U. 2004 No 11, item 94 with later changes) on supervising the technical state of equipment used to do treatments of chemical services is valid. The act imposes the obligation to test agricultural sprayers in respect to their technical state.

The ways of doing tests and developed methodologies should include such an essential element like the lack of ecological threats, including threats for human health and life. These threats, in the case of analysed testing methods, can occur at the stage of preparation, realization and termination of the testing process and can also result from inaccurate testing procedures.

**6.2. Procedures of test sprayers**

The procedure of preparation for tests (washing the sprayer) and reliability as to the place and the way of management of the liquid solution used in the tests arise doubts considering the item (the sprayer) preparation for tests and its termination. The statement that used liquid can be a solution results from Swedish and Belgian research.

The process of rinsing the sprayer liquid system decreases the concentration of a biologically active substance which in used water can equal 0,02 – 0,3% of the concentration occurring in working liquid but it will still exceed several dozen times the level of the pesticide content in drinking water which equals 0.1μg/1 (Nilssen, 2001). Also for all above reasons rinsing containers of pesticide solutions must be careful and repeated (Mostade et al., 1996).

Referring the pesticide concentration to standards for drinking water results from the fact that when employees stay in the area of a groove table they may inbreathe contaminated air (of 99% humidity). The work of the sprayer in the area when the employees responsible for service of measuring devices stay and their direct contact with atomized liquid can cause so called "remote results" (Luty et al., 1997).

Valid methods of testing the technical state of nozzles vary in assumed ways of measurement. The measurement does not concern the outflow but the fall of atomized liquid, which is confirmed by the lack of the equivalence of evaluations for measurement results received while using different types of groove tables.

A long-term operation leads to the wear-out of the nozzles and the intensity of this process and its results depend on many factors such as the material of the nozzles, the type of applied plant protection products, the storage conditions and the operation correctness. These changes are expressed by the increase of both single outflow and droplet trace spectrum (VMD-volume median diameter) (Reichard et al., 1991; Ozkan et al., 1992; Czaczyk, 2001). Pace of wearing out and a change of parameters of nozzles work depend on the type of material of which they were made of and also on the nominal liquid outflow of the nozzle. Practically useful parameters of nozzle work can change but they are impossible to be evaluated on groove tables. CV coefficient can be improved or worsened despite the stated increase of liquid outflow intensity and droplet spectrum.

From other studies it results that 15% and even greater increase of single outflow does not have substantial impact on worsening of the CV coefficient (Oznkan, 1992; Czaczyk, 2001). Moreover, changing the place of the nozzle installation on the field beam of the sprayer causes the change of CV coefficient within 1-4% and the measurement itself concerns evaluation, work quality of the field beam with a given way of nozzle installation (Huyghebaert et al., 1996; Sawa, 1999).

Improperly methodically, for the same evaluation criteria it is acceptable to use groove tables with different width of troughs (100 mm or 50 mm). Such tables are used in some sprayer control stations. It causes that with the evaluation criterion according to deviation from the mean value, the number of measuring vessels beyond tolerance will be higher for the table of troughs of 50 mm wide. Results of theoretical studies carried out in the University of Life Sciences in Lublin and laboratories in PIMR (Przemysłowy Instytut Maszyn Rolniczych - Industrial Institute of Agricultural Engineering) confirm this (Sawa et al., 2002; Szulc and Sobkowiak, 2002).

Tests are carried out according to "Instruction of doing tests of equipment for using plant protection products" which was approved by Główny Inspektorat Ochrony Roślin i Nasiennictwa (Main Inspectorate of Plant and Seed Protection) (GIOR). In the instructions there are specified sets of sprayers which should be controlled and in the case of nozzle testing two evaluation methods were accepted: measurement of distribution irregularity of atomized liquid fall or measurement of single outflow intensity. It is assumed that under the test conditions defined in the regulation both methods are possible to be used and obtained results will be useful for agricultural practice.

According to the Ministry of Agriculture and Rural Development (Rozporządzenie…, 2001) two parallel methods to evaluate the technical state of nozzles are valid:

1. Measurement of distribution irregularity of liquid outflow,
2. Measurement of single outflow intensity for each nozzle.

The Directive of the European Parliament and the Council 2009/128/WE of 21 October 2009 was published in 2009. It established the frames of community acting for balanced pesticides application. According to the resolutions included in the directive, the equipment for using pesticides must be in conditions that allow its effective and reliable application (Wehmann, 2012). Precise data on requirements, which must be fulfilled by equipment being already in use, are included in the enclosure II of this directive. Components of the sprayer like: transmission of power, liquid system, filtration system, working efficiency of the main valve and anti-drop valves can be made through examination and functional tests of these elements. Correctness of manometer work should be checked on a special press and a model manometer. A separate test procedure refers to tests of nozzles installed on the sprayer. It should be checked if nozzles are of the same type and do not have any outside damages. The enclosure II of the directive says about testing two parameters of nozzles that:

- nozzles must work properly to limit dripping after finishing spraying. To ensure the uniformity of spraying stream, outflow intensity in individual nozzles cannot be significantly different than data which are in the tables of outflow intensity provided by the producer;

- distribution of working liquid on the target surface - horizontal and vertical (in the case of using in vertical crops) must be even.

The way of doing control tests of a used agricultural sprayer was also illustrated in standards PN-EN 13790-1 (2004) for field sprayers and in the standard PN-EN 13790-2 (2004) for orchard sprayers. In these standards the way of presenting individual sets was discussed and admissible tolerance, in which obtained test results for efficient equipment should be placed, was given (Osteroth, 2010).

One of the items of the text included in the directive is a definition of a professional user. Article 3 of this directive includes a definition that *"a professional user means any person who uses pesticides in professional work, including operators, technicians, employees and self-employed people in an agricultural sector and other sectors." Except from taking care of a technical state of equipment for pesticide application professional users should also periodically test sprayer calibration. Item 5 of article 8 says: "Professional users do regular calibration and technical servicing of equipment for pesticide application according to the recommendations given during trainings which were mentioned in art.5.*

Sprayer calibration consists in synchronization of three essential working parameters of the sprayer, namely: working speed of aggregate, working pressure and size of nozzles. Working speed and the size of working pressure are the parameters, which the user can choose depending on the conditions of the application. Choosing a suitable size of the nozzle and a size of working pressure, we can regulate a doze with assumed speed, and influence the size of received droplet spectrum (Doruchowski et al., 2012).

### 6.3. Methods of agricultural nozzles tests

In some countries a preferred method of testing nozzles in terms of intensity of liquid outflow allows precise checking of each nozzle and comparing if single costs of nozzles are the same as the producer says. Efficient nozzles are those ones whose single costs do not differ from nominal ones by 10%. Having information about efficiency of nozzles in terms of their outflow intensity we can correctly do the process of sprayer calibration.

The example of such a device for testing the size of liquid outflow from nozzles used in sprayer control stations is the Belgian device of ITEQ. This device allows fast and efficient control of disassembled nozzles from the field beam of the sprayer (Figure 6.1).

This device has a closed liquid system. It is of a small size thanks to which it can be used in service cars for itinerant sprayer control. The electronic system of measuring set allows automatic recording of size of individual cost for each nozzle, recording results in a database and printing a test protocol indicating which of the tested nozzle fulfils correctness criteria in terms of outflow intensity. This device meets requirements of item 9 enclosure II for Directive 2009/18/WE in terms of testing single cost. However, only one parameter of nozzle work is tested.

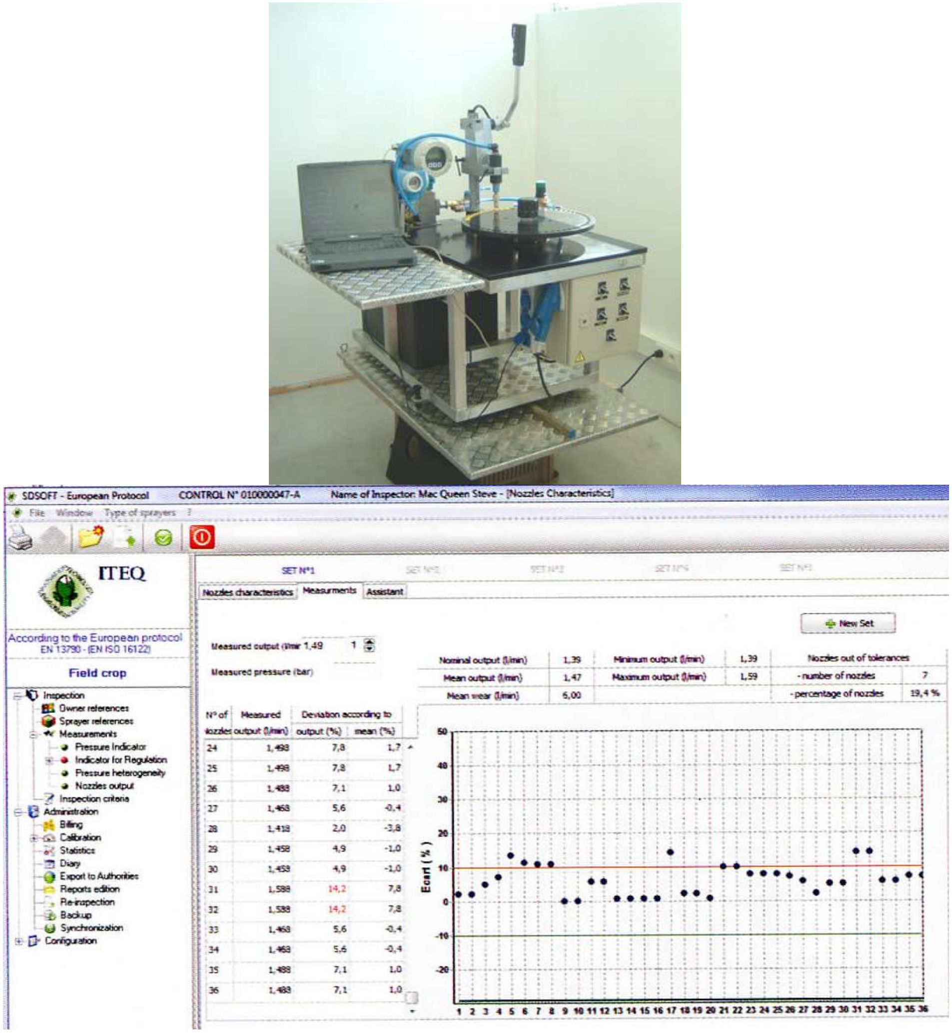


Figure 6.1. A device of ITEQ company for testing intensity of liquid outflow from agricultural atomizers and an exemplary protocol of these tests

A technique of testing agriculture nozzles with a method of measuring intensity of liquid outflow from nozzles installed on the field beam of the sprayer is also admissible. While doing these measurements there is a risk of receiving results of single liquid outflow from the nozzle distorted by disturbances resulting from working efficiency of equipment elements of the field beam which are anti-drop valves (Tadel, 2012).

Measurement of liquid outflow intensity can be done with the use of electronic devices equipped with a flowmeter. Such devices can record obtained results in a database. Devices equipped with measuring cylinders are used for testing nozzles installed on orchard sprayers.

For agricultural practice especially important are the following parameters of spraying: droplet spectrum of spraying and uniformity of their distribution on a protected area, which in turn, depends on a technical state of equipment used for plant protection. Meeting all these requirements is possible if suitable setting of parameters of sprayer work are guaranteed (pressure, setting of sprayer field beam or working speed). Uniformity of the stream of atomized liquid is a very essential parameter, which decides about the quality of giving working liquid on the atomized surface. Item 10 of enclosure II of the EU directive says that also uniformity of the stream of atomized liquid should be tested while doing periodical tests of sprayers. These tests are done on electronic groove tables with groove spacing of 100 mm. Many countries have introduced this method as a basic method used in sprayer control stations. The example of such an electronic device is presented in Figure 6.2.

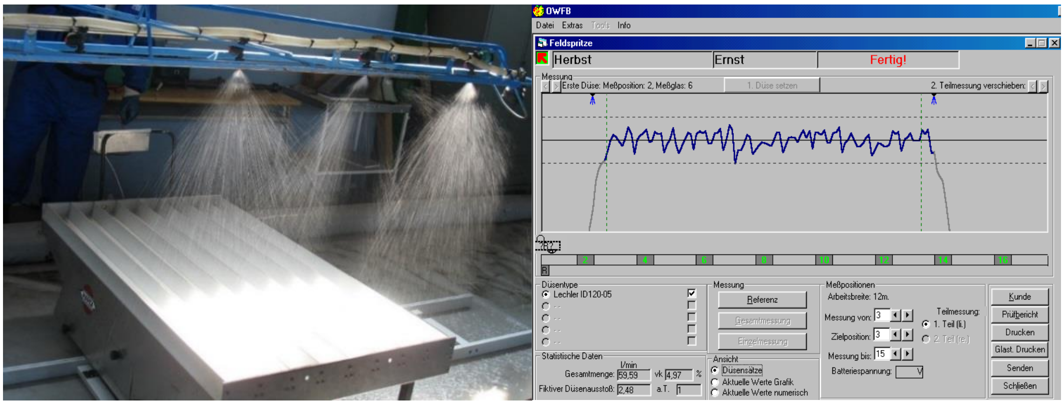

Figure 6.2. The electronic groove table for testing uniformity of distribution of atomized liquid fall and a protocol from these tests

During the test the electronic table is placed under the field beam of the sprayer and it collects data from the whole width of the working beam, moving gradually under the whole width of the beam. Data obtained from the test is presented in a graphic way by counting the coefficient of variation for the whole width of the work of the field beam. A field beam is considered efficient when the coefficient of variation (CV) of atomized liquid fall is not higher that 10%. Slotted nozzles give liquid stream in the form of fans, which overlap one another. The fan of such stream results from at least three nozzles. Using this method it is impossible to indicate which nozzle works improperly, it is only possible to indicate the place in which improper work of nozzle occurs.

This measuring method of uniformity of nozzle liquid fall should be done in closed rooms in order to exclude the influence of atmospheric conditions on the test result. To do these tests the sprayer should be aggregated with a tractor and a sprayer container should be filled with water. A serious problem is to keep BHP regulations (health and safety regulations) of tests, which are done in closed rooms and include already used sprayers contaminated with unknown pesticides. These problematic aspects were the subject of analyses in which limitation of currently used methods of testing nozzles were indicated. In Figure 6.3 threats for people doing tests of distribution uniformity of atomized liquid stream are presented. It is recommended that sprayer users provide sprayers for tests rinsed at least 3 times, however we cannot be sure that there is no working liquid left in water provided with the sprayer for tests.

Figure 6.3. Threats for operators doing tests of distribution of nozzle liquid fall on the groove table

Methods of testing nozzles in term of size of outflow intensity and methods of stream fall of nozzle liquid give different information about the state of nozzles. However, these results cannot be compared to one another. Defining these differences is the basis to evaluate recommended methods in terms of fulfilling, quality of ecological, methodical and utilitarian standards. Most of these requirements are connected with rules assigned to the conception of balanced development including balanced agriculture. Methods of sprayer testing, implemented to field tests, in comparison to laboratory tests, must be of higher margin of safety in every three groups of requirement standards, keeping the order mentioned above.

### 6.4. Device testing to investigations of crevice agricultural nozzles

The techniques of nozzle testing mentioned are used with the application of tools and manual or semi-automatic instrumentation. Langman and Pedryc (2003) paid attention to this, indicating the lack of devices for automatic evaluation of a technical state of agricultural nozzles.

Facing expectations, a device for complex testing of nozzles used in agricultural sprayers was constructed. It was assumed that it would be possible to do tests of nozzles in laboratory conditions in time convenient for users. A construction and a structure of the device for complex testing of evaluation of the technical state of agricultural nozzles is based on a patented invention no PL 193 975 B1 (Sawa and Parafiniuk, 2001).


Figure 6.4. Device testing to investigations of crevice agricultural nozzles

The automatic device for complex evaluation of the technical state of agricultural nozzles was built in Department of Machinery Exploitation and Management of Production Processes of University of Life Sciences in Lublin within the international research project titled “Development of methods and a device for complex tests, quality of work of agricultural nozzles and validation of these methods” (no of the subject MNiSZ: Decision NO 493/N-Belgia/2009/0 according to: UP Lublin No TKR/PBM/92).

The device for complex tests of agricultural nozzles built within the research project realization provides the user of nozzles reliable and repeatable results. With this device it is possible to test parameters such as: the size of liquid outflow intensity with assumed pressure, the angle of the stream of nozzle liquid, the width of the nozzle liquid stream and asymmetries of spraying. These results allow evaluating a technical state of nozzles and, it helps make up decisions as to the duration of their conditional use, or the need for replacing for a new one.

Testing the set of agricultural nozzles on the testing device allows collecting results in a computer database. The testing device works automatically. The next test is possible - max up to 40 nozzles both in one repetition or repeated testing of particular nozzles (free number of repetitions). These data can be used for the simulation of the work of the field beam built in a computer programme or a spreadsheet programme. Such simulation gives approximate possibilities of evaluation, quality of work of a sprayer field beam (Parafiniuk at al., 2011).

To obtain reliable and repeatable results of tests on the device for controlling the technical state of agricultural nozzles it is necessary to do some necessary actions according to predicted and developed procedures of acting before staring tests. According to the procedures this action concerns both preparing a device and preparing nozzles for tests on this device.

Before starting tests on the testing device it is necessary to introduce basic parameters concerning the user of tested nozzles. These data allows searching archival results. Also such parameters of device work are recorded. The parameters are as follows:

- Liquid pressure during the test
- Received liquid cost during the test
- Transverse distribution of atomized liquid fall over the table

Obtained results of tests of single nozzles allow building a virtual field beam and evaluation of uniformity of nozzle liquid fall on the tested surface. The obtained set of results allows simulation of choice, setting individual nozzles on the sprayer field beam as well as referring these test results to other evaluation methods of nozzle work e.g. using the electronic groove table. The way of constructing the virtual field beam is presented in Figure 6.5.

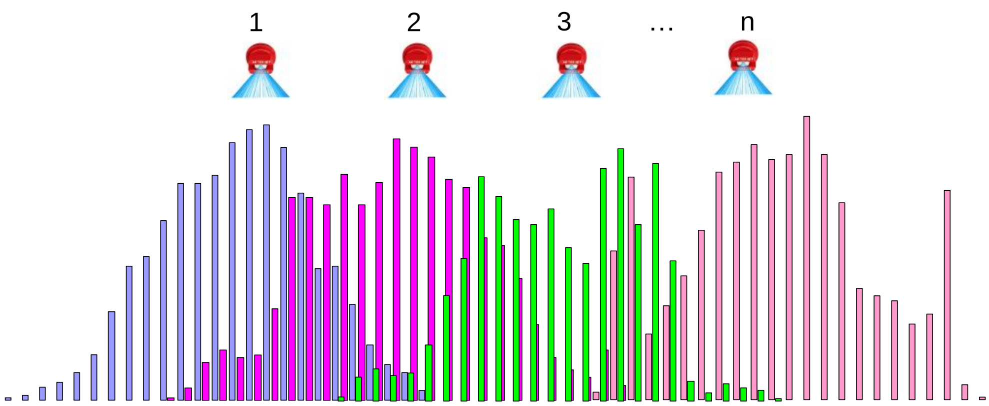


Figure 6.5. The way of constructing the virtual field beam

The amount of collected liquid in measuring vessels is compared in such a way so that distributions of atomized liquids overlap one another and nozzle axes are away from one another, of every 10 measuring grooves, which gives identical liquid distribution like on the agricultural sprayer. The total amount of liquid from individual distributions allows receiving amount of liquid occurring on a given width of the sprayed area. Based on these results it is possible to count an average size of atomized liquid fall, a size of standard deviation and the coefficient of variation (CV). The value of this coefficient is expressed in a work quality of the agricultural sprayer.

Characteristics of nozzle liquid fall compared on a virtual groove table are presented in figure 6.6 and 6.7. Two kinds of slotted nozzles operated in agricultural conditions TeeJet XR 110 VK 24 pieces and TTD JET RS110 R 20 pieces were used for the tests. Liquid pressure amounted 3 bars, height of installed liquid over the groove table amounted 500 mm, time of individual test of an nozzle equalled 60s. Obtained results were compared using an Excel spreadsheet programme. To define the mean value and standard deviation, extreme values were rejected as it happens in tests of the sprayer field beam done with the help of mobile groove tables.

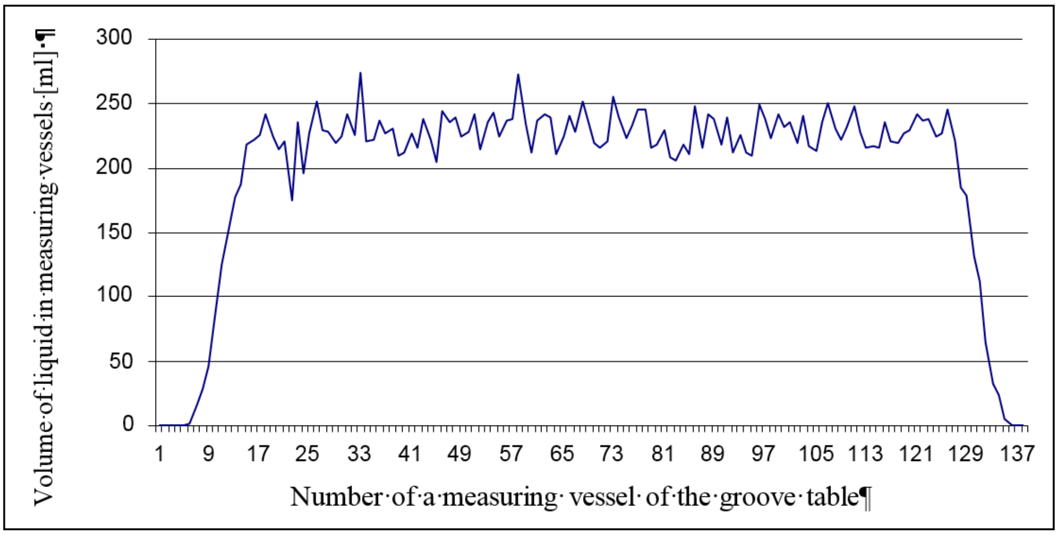


Figure 6.6. Characteristics of nozzle liquid fall obtained on a virtual groove table of grooves 100 mm wide for the sprayer XR 110 VK with the pressure of 3 bars. CV =6,43 %

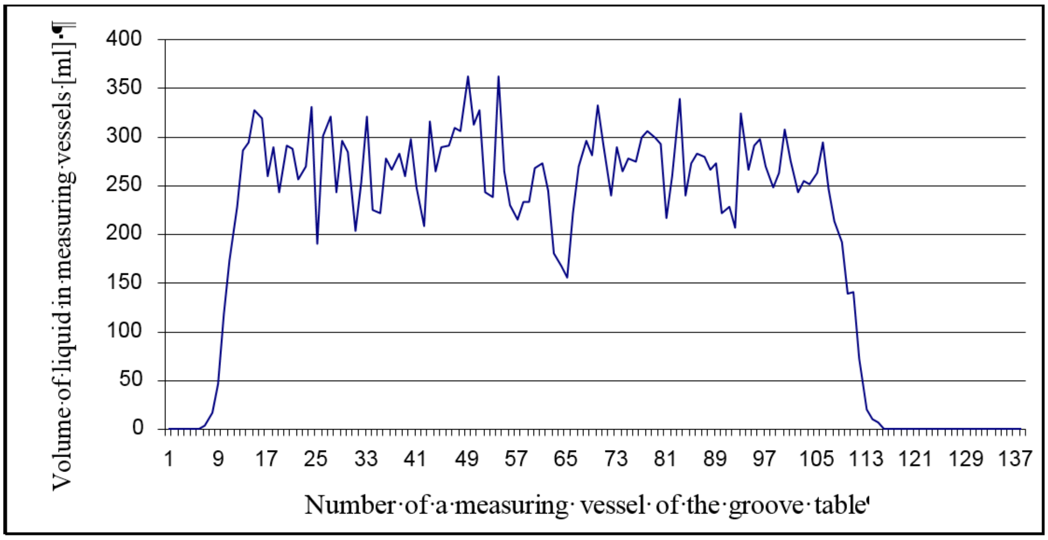


Figure 6.7. Characteristics of nozzle liquid fall obtained on a virtual groove table of grooves 100 mm wide for the sprayer TTD JET RS 110 R with the pressure of 3 bars. CV =15 %

Along with the device for complex tests of agricultural nozzles the programme for nozzle setting optimization was written in the R programming language. The programme does the conversion of data obtained from the groove table of the device every 50 mm groove spacing on such a width of grooves (100 mm) that is used for testing distribution on the sprayer field beam. Then it does such a simulation of the order of setting-up nozzles on the sprayer field beam so that it would be possible to obtain possibly the smallest coefficient of variation (CV). Due to the large number of combinations of nozzle order settings (for 20 nozzles it equals 20!) the programme is able to enter any number of done combinations of the nozzle set-up. It results from the research carried out in University of Life Sciences in Lublin that 10000 used simulations give a satisfactory result and that increasing the number of simulations in a very minimum way influences receiving possibly the smallest CV.

The measuring method of single nozzles and then their combining in the virtual field beam was compared with the method of testing distribution of the nozzle liquid steam over the groove table of 100 mm groove spacing. Comparative research were carried out in the accredited laboratory Agricultural Research Centre (CRA-W), Gembloux in Belgium. Obtained results allow to state that the received result of the coefficient of variation differ from the result received for the virtual groove table on average of approximately 3% (Parafiniuk, 2013).

### 6.5. Conclusions

Each of the used measuring methods is burdened with some error of measurement, inaccuracy or a wrong interpretation of received results. Taking into consideration the occurrence of the factor mentioned above and conditions of testing agricultural sprayers which are already in use a device and a method of measuring agricultural nozzles were developed. It was assumed that testing single nozzles according to the standard for these type of tests and then doing the conversion of obtained results to requirements included in the standard for testing a field beam allows frequent testing of the condition of the sprayer beam. Currently such a measurement is done every three years. The method of nozzle testing on the device may be done in any season of the year in laboratory conditions and the obtained result is compared to the one obtained on the electronic groove table. The test is also possible without a direct participation of an employee who operates the device while testing because the whole process is done automatically. Such a test allows limiting to the minimum the threat for the staff of the sprayer control station of the remaining plant protection substances which are in controlled sprayers.

Based on the performed analysis of the way of doing tests in sprayer control stations, technical evaluation of work efficiency of agricultural nozzles can be done and the following conclusions can be formulated:

1. The presented testing device is ready to measure simultaneously the individual output and spray pattern of all types of flat fan nozzles.
2. Received results indicate that there is a possibility to assess the technical condition of spray boom using the method of assessing the technical condition of single sprayers.
3. Evaluated data is comparable to the one received using the electronic groove table.
4. Tests on the device for complex evaluation of a technical condition of agricultural nozzles allow minimizing the threat for the staff of the sprayer control station.
5. The obligatory control of equipment for pesticide application should be carried out using such instruments to ensure security for people and to protect the environment.

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# 7. FARMERS COLLABORATION – THE WAY FOR IMPROVING SUSTAINABLITY

*Edmund Lorencowicz, Jacek Uziak*

**Keywords:** *Lublin province agriculture, Polish agriculture, collaboration forms, farmers co-operation, cost of mechanization*

## 7.1. Introduction

The definition of sustainable agriculture covers not only the ecological and technological aspects but also economic and social. As one of many definitions of sustainable agriculture (SAI, 2013) states: "Sustainable agriculture is the efficient production of safe, high quality agricultural products, in a way that protects and improves the natural environment, the social and economic conditions of farmers, their employees and local communities, and safeguards the health and welfare of all farmed species". Those aspects are especially important in case of small, family farms with area of a few hectares and economic size of a few ESU.

It is evident that the current agriculture does not allow a family farm to operate on its own without collaboration with other entities, and not only in terms of product marketing but also in terms of the organization of production processes. The examples of different types of partnership not only in the European countries, where the farmers strongly cooperate within market environment as well as with each other, indicate advantages and positive aspects of collaboration. The need for collaboration covers also the production of mechanization in order to limit the high investment level, increase work efficiency and obtain extra income.

Without doubt, farmers' collaboration, in terms of planning and realization of work activities, would improve the economic results of farms as well as quality of life for farm families. This means that some factors of sustainability will be improved.

## 7.2. Specific features of agriculture in Poland and in Lublin Province

Poland is a country with big diversity in terms of farms area structure. That diversity is regional – in west and north of Poland the average farm area is higher than in other regions.

There are regions in the east part of Poland with highly fragmented farms (Małopolska region – has an average farm area of 3.88 ha) and also regions with larger farms (like Zachodniopomorskie - with an average farm area of 30.67 ha and

28% farms over 15 ha). The Lublin region has an average farm area of 7.45 ha with share of farms over 15 ha 9% (Table 7.1, Figure7.1).

Table 7.1. General characteristic of agriculture in Poland and Lublin region (2010)

| **Specification** | **Poland** | **Lublin Province** |
|---|---|---|
| Number of farms above 1 ha | 1,562,600 | 189,900* |
| Average farm arable area | 9.76 ha | 7.45 ha |
| Number / Percentage of farms below 5 ha | 861,800 / 55.1% | 102,500 / 53,4% |
| Number / Percentage of farms above 10 ha | 349,100 / 22.3% | 34,500 / 18.2% |
| Number / Percentage of farms above 50 ha | 27,150 / 1.7% | 1,450 / 0.8% |
| Area distribution of farms above 50 ha | 25.7% | 11.7% |
| Average age of farmers | ~ 47 years | |
| Percentage of farmers below 36 years of age | 14.7% | |
| Percentage of farmers above 65 years of age | 8.4% | |
| Number of tractors | 1,471,000 | 173,000 |
| Average power of tractor | ~ 40 kW/54,4 HP | |
| Average age of tractors | ~ 23 years | |

* 12.1% of total number of farms in Poland

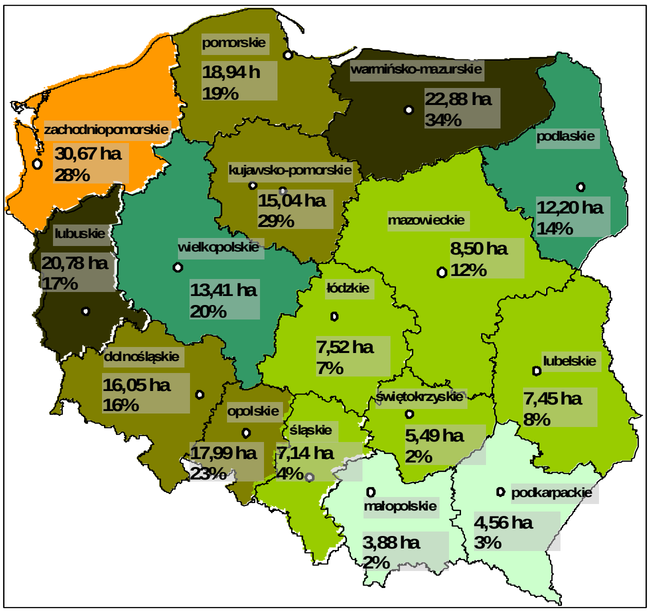



Figure 7.1. Average area of farms in Polish provinces in 2010 (in ha, % of farms over 15 ha)

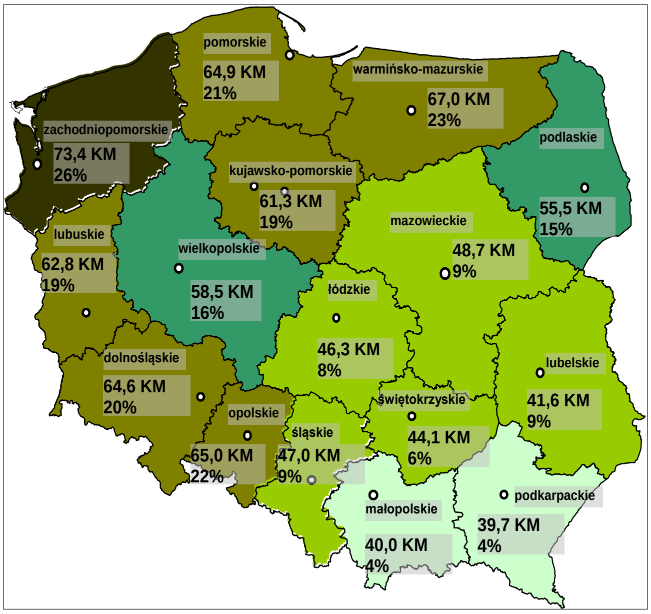


Figure 7.2. Average tractor power in Polish provinces in 2010 (in HP (KM), % tractors over 100 HP)

In comparison to the average values for Poland the agriculture in Lublin region is more fragmented, with not even 1% of farms above 50 ha whereas the region takes 11.7% of total arable area. The average age of the farmer is 47 years and more or less every seventh farmer is younger than 36 years. The trend noticed in the last years is the increase in the farms areas and the reduction in the farmers' age.

Practically every farm with an area above 5 ha has a tractor and a set of basic machines. The average power of tractors is 40 kW and their age is more than 23 years. Only farms above 50 ha have full complement of machines to cover all required jobs.

### 7.3. Forms of collaboration in mechanization

Proper realization of agricultural activities requires access to many machines and equipment, which in general is very expensive (Culpin 1975). It is quite normal that in the case of small farms, with small areas and low income, it is not possible for the farmer to have its own machinery. Support by EU funds has strong impact in costs reduction (Lorencowicz and Cupiał, 2012). One of the other possible solutions is the collaboration between farmers (Kooperationen,2005). In most cases, farmers collaborate with each other both formally and informally, using a variety of methods for work organization and to settle costs and efforts. This is typical in countries with a majority of small, few hectares, farms but also in case of bigger farms, even with areas of hundreds of hectares (de Toro and Hansson, 2004; Lorencowicz, 2005).

The possible solutions for farmers' collaboration can be classified as follows (Landers, 2000; Theunissen, 2002; Weshe, 2004; Witney, 1988):

- neighbours' cooperation,
- machinery co-operatives,
- machinery syndicates,
- machinery rings.

Neighbours' cooperation is the traditional form of collaboration and is also very popular in Poland. It can be contract work or machinery exchange. It is recommended that the jobs are accounted for but it happens quite rarely. In practise the settlement of cooperation depends on local conditions and customs.

Machinery cooperatives are hardly found in Poland. In that type of collaboration the purchased machines belong to the cooperative and the jobs done are accounted according to agreed rates. One of the reasons for that form not to be popular in Poland is negative experiences from the communist period.

Machinery syndicates or pools are appropriate solutions in the case of specialised machinery. Members of syndicate are co-owner of the machinery. Once again, the pools created can be formal or, more often, informal. Once again, it is strongly recommended that the syndicates would operate on the basis of agreed rules and would use proper accounting procedures.

Machinery rings are practically unknown in Poland. In 1990's there were some attempts of creating rings, however they did not survive. That form of cooperation has a lot of advantages and is popular in Germany and some other European countries. In recent years the rings are evolving and currently it is not only the form of organization of machine work but allows also for collaboration in terms of purchasing of means of production as well as trading of agricultural products.

There are a lot of advantages of farmers' collaboration. These are:

- reduction in the cost of machine operation, mainly due to reduction of fixed costs,
- savings in the cost of mechanization,
- reduction of investments outlays
- improvement in the access to new technologies
- improvement in the specialization, hence increase in the income

- attain extra income from additional activities,
- increase in work effectiveness, which can give the farmer more free time.

Also the sole ownership has some advantages, like:

- adding value to farm business in the form of an asset,
- timeliness and flexibility of using machinery,
- matching implement to farmers situation comparing to using contractors or belonging to the syndicate,
- ability to increase income via contracting in work.

This is important, but, in the case of small farms financial limitations are the main barrier.

### 7.4. Case studies

Case 1. Collaboration of selected group of farmers

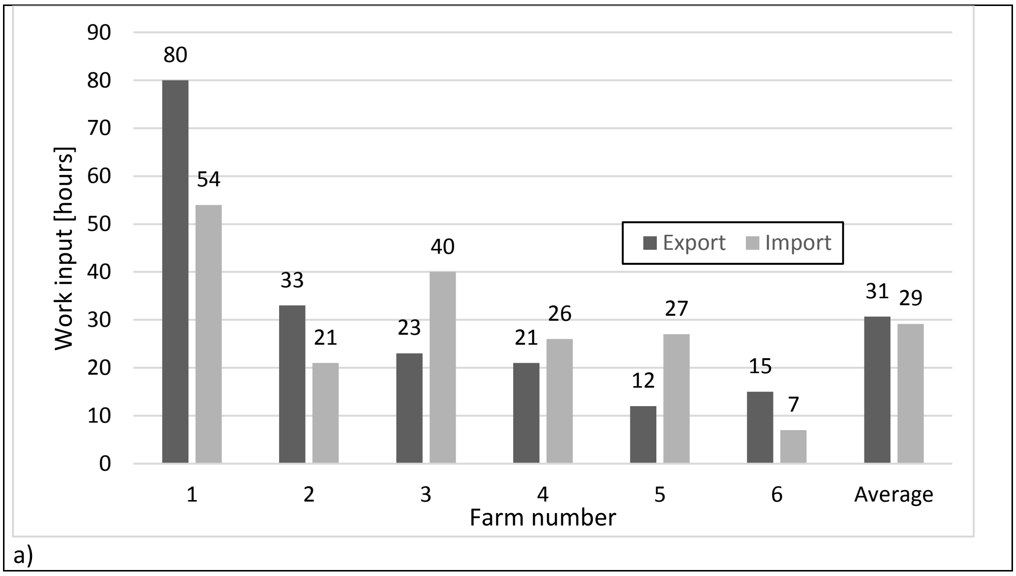
Analysis was performed for 6 selected farms in the Lublin Province (Pawluk, 2007). Farm owners were members of the same family and collaborated with each other in an informal way for many years. It was mainly neighbours' cooperation, settled in monetary terms. However, there were also settlements by exchange of work and agriculture products. The farms under consideration were diverse in terms of agricultural land areas and technical equipment (Table 7.2). The agricultural areas varied from 8.57 ha (the smallest farm) to 76.47 ha (the biggest farm).

Table 7.2. Characteristics of selected farms

| Item | Farm Number | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **Average** | **Total** |
| Agricultural area [ha] | 76.47 | 47.00 | 18.73 | 16.30 | 13.15 | 8.57 | 30.04 | 180.22 |
| Value of machinery [thous. of: PLN/ EUR] | 1,905.7 / 476.4 | 964.6 / 236.7 | 109.2 / 27.3 | 183.8 / 46.0 | 188.4 / 47.1 | 205.9 / 51.5 | 592.9 / 148.2 | 3,557.6 / 889.4 |
| Value of machinery per ha [thous. of: PLN/ha / EUR/ha] | 24.921 / 6.230 | 20.522 / 5.138 | 58.30 / 14.575 | 11.277 / 2.807 | 14.325 / 3.581 | 24.030 / 6.008 | 16.818 / 4.205 | X |
| Tractor power per 1 ha [kW/ha] | 2.7 | 3.0 | 1.2 | 2.1 | 2.6 | 2.6 | 2.5 | X |
| Machinery average age [year] | 10.2 | 21.7 | 17.3 | 23.5 | 19.8 | 19.0 | 18.7 | X |

*PLN-polish currency (złoty)*

The total value of machineries varied from EUR 27,300 to EUR 476,400. Tractor power saturation was on average 2.5 kW/ha. The machinery was relatively old as the average age was almost 19 years and it varied from 10.2 to 21.7 years. The above indicates low investment ability of the farms.



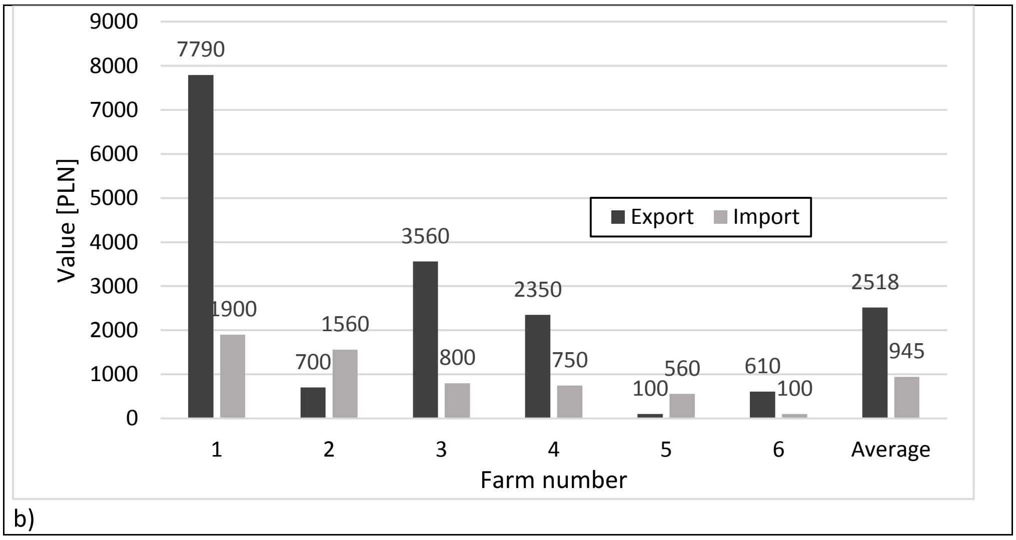




Figure 7.3. For selected farms: a) Export and import of work hours
b) Income (exported) and cost (imported) of contract work

The number of contract work done by a particular farm depended on its work and machinery capacity and varied between 12 hrs. to even 80 hrs. per year (Figure 7.3 a). The yearly income varied between PLN 100/EUR 25 to even PLN 7,790/ EUR 1,947 (Figure 7.3 b).

The analysis of the operation cost of the machinery used in farmers' collaboration showed its reduction due to the increase of machines use during a year. Such reduction reached even 62% in the case of a combine harvester.

Farmers assessed the collaboration positive as: 'Very Good' – 2 answers, 'Good' – 3 answers and 'Acceptable' – 1 answer.

Farmers that participated in the survey wish to have more neighbouring farmers taking part in the collaboration, which can reduce the costs and rent prices. The calculation done for a combine harvester indicates that even a small increase in usage can reduce the yearly operation costs even by 62% (Figure 7.4).

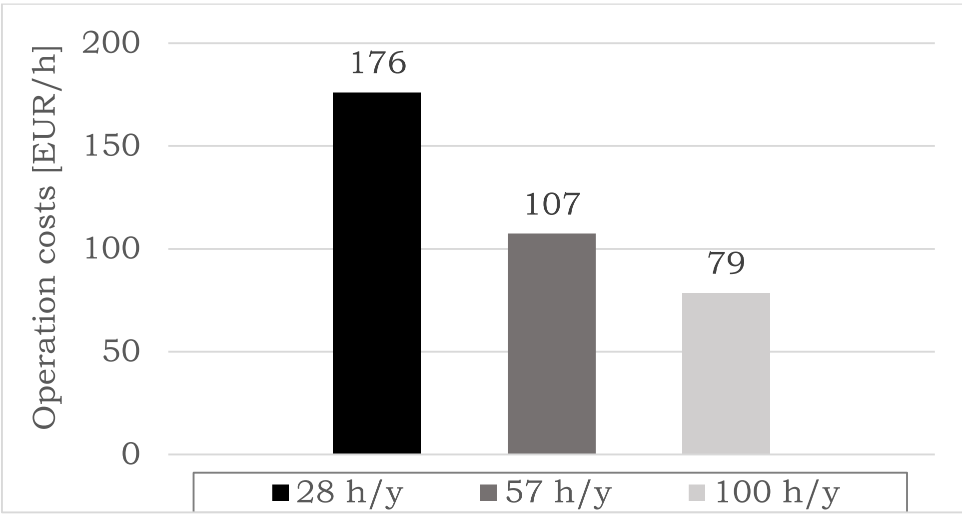



Figure 7.4. Changes in the unit operation costs (in euro per hour) of combine harvester as a function of yearly usage (hours per year)

Case 2. Collaboration of farmers from selected village

Investigation in order to assess cooperation ties created between farmers was done in 2004 (Kowalczuk, 2005; Lorencowicz, 2006). The study covered all 20 farms from one village. Structured interviews were used to collect the data.

The average arable area of farms was 24.83 ha (from 10 to 46 ha). They were equipped with tractors (from 1 to even 4, with average of 2.3 tractors per farm) and a set of machines (from 14 to 32 items). Almost 50% of the farms had combine harvesters (9 items) and their technical equipment was better both in terms of number as well as quality in comparison to the region average. The above was due to specialised production and also to the fact that their average size was more than 3 times bigger than the region average. However, despite a higher income, a lot of machines were old including the use of horse cart as the form of transport. The average age of tractors was 16.3 years whereas the combine harvester's average age was 20.9 years. It is worth noting that even such old machines were used for cooperation. The reason for collaboration between farmers was that actually there was not a single farm with all the required machines.

The most popular machines to be taken from outside (import) were transportation trailers, vacuum tank spreader and combine harvesters. Those three machines constituted together 25% of all cases, whereas there are in total 36 types of machines in cooperation. The most popular machines to be taken outside (export) were transport trailer and tractor (17% cases) and the rest of 83% cases were covered by 45 different tools, machines and tractor aggregates. All farmers utilized part of technical equipment within machine sets. Depending on the farm this was from 1 to 11 machines. There were 24 types of machines used in that way, and in half of the cases it were machines for sowing and planting. Typically such machine set was created by two partners, but there were five cases of 3 partners, three cases of 4 partners and even one case of 7 partners. There were also cases of cooperation in case of other machines useful in farm work as chain saw or workshop equipment (welding apparatus).

The application of own technical equipment outside of the farm increased the yearly usage from few to few dozen hours. The most used outside machines were: manure spreaders – 315 hrs (mainly in transport), tractors – 228 hrs and transportation trailer – 196 hrs. Despite such broad range of cooperation the main form of settling was non-monetary, such as manual labour or machine work (Figure 7.5). Interestingly, the farmers more often gave information about monetary settlements for outside machines (import) than their own machines (export). Such asymmetry can be attributed to fear of the farmers to disclose extra income.

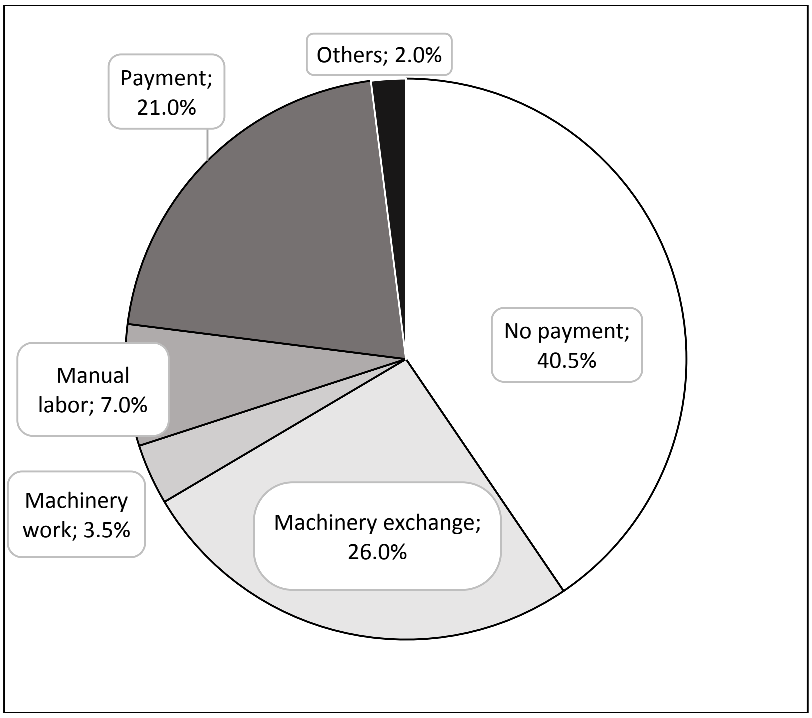


Figure 7.5. Form of settlement for machinery

Figure 7.6 shows the complexity of cooperation ties. The figure presents ties only for two selected farms.

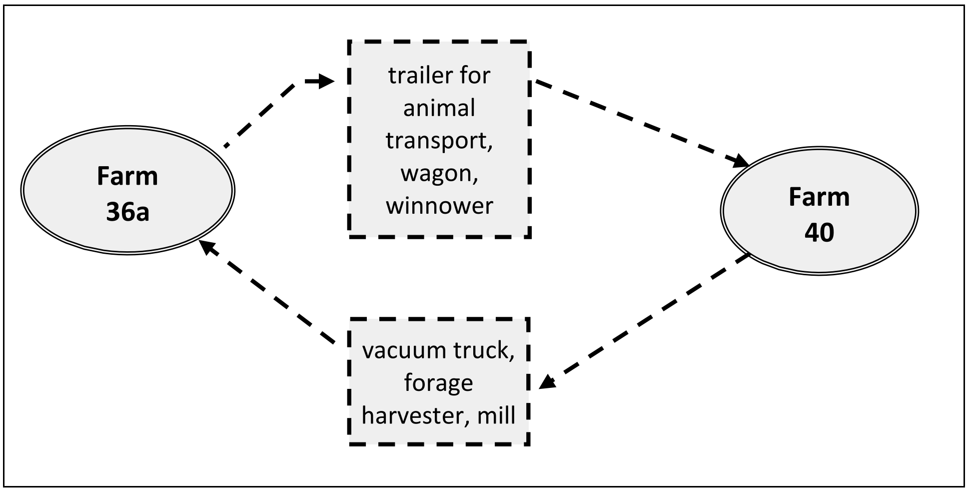
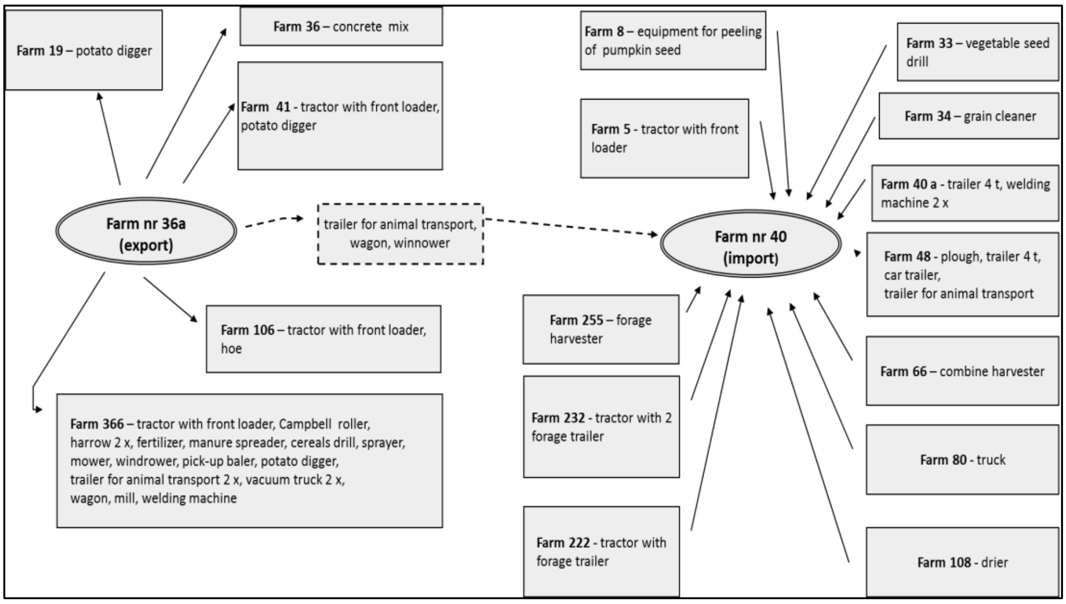
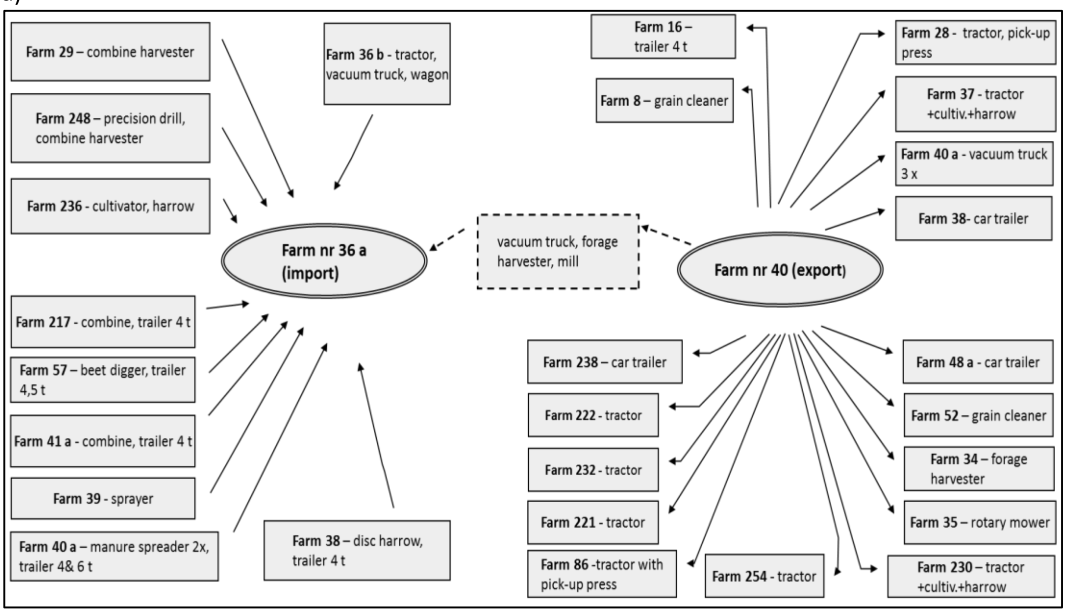


Figure 7.6. Cooperation ties between two selected farms




a)




b)

Figure 7.7. Example of cooperation ties of 2 selected farms

a) farm 36 a - export, farm 40 – import of machinery work;
b) farm 36 a – import, farm 40 – export of machinery work

Apart from small, mutual cooperation there were several other connections with other farms in the system (Figure 7.7). Farm no. 36a exported machines to other five farmers and imported from ten, while farm no. 40 exported machines to seventeen farmers and imported from twelve (excluding farm no 36a). This example indicates large and complex systems of cooperation; the above example was no exception within investigated farms.

This study proved that, apart from seldom cases, there are no farms isolated from the surrounding and cooperation in terms of machinery is common. Such cooperation is informal and farmers do not create any rules (for instance in the form of written agreement of regulations). Relations between partners are formed by local tradition and different type of neighbour and family connections. Access to others, apart from own ones, technical equipment increases not only the level of work mechanization but also reduces production costs, in the Polish conditions from 25% to even 40%.

It is envisaged that the level of cooperation can be stimulated not only by advisory activities but also by appropriate financial schemes encouraging joint machines purchase or increase of its usage, for instance is service.

### 7.5. Conclusions

Farmers' collaboration is an important form of satisfying technological needs in the case of fragmented agriculture. At the same time it reduces the costs and outlays. It allows the farms to fulfil the requirements for sustainable agriculture, improving, at the same time, the quality of life for farm families.

According to the farmers under investigation, the most important factor in favour of collaboration was the lack of own equipment and, in the case of elderly farmers, the limited possibility of own work. Despite relatively low economic gain and frequent use of non-monetary forms of settlements, the farmers' collaboration practised throughout the years afforded proper operation of the farms and protected their owners in the case of lack of technical means.

The types of collaboration presented above cover only issues related to organization of work of machinery in farms. Certainly farmers develop cooperation in other areas. It includes procurement of means of production, trading of the agricultural products, advisory or training activities. All of such actions increase farmers' income, their living standards, professional satisfaction and also fulfilment of their personal plans.

In conclusion, it is reasonable to state that farmer's collaboration, also in the aspect of machinery using and work organization, improve the sustainability in social and economic areas.

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## 8. VALUE OF AGRICULTURAL LAND ON FARMS WITH DIFFERENT AGRICULTURAL PRODUCTION SYSTEMS

*Sławomir Kocira, Edmund Lorencowicz, Anna Kocira, Milan Koszel*

**Keywords:** *value of agricultural land, agricultural systems, farms*

### 8.1. Introduction

According to the Polish Civil Code (Kodeks,1964), agricultural lands can be defined as the ones that are or may be used in order to conduct manufacturing operations in agriculture as regards to growing plants and livestock rearing (including the horticultural, orchard and fish). The Act on the agricultural system formation defines agricultural lands as it is stated in the Civil Code, except the lands allocated to spatial development regarding other, non-agricultural purposes.

Agricultural lands significantly vary in value. In this respect, almost no other group of assets is characterized by such variation in value. The main factors which affect the value, are synonymous with the typical characteristics of agricultural lands, namely that they are not movable, they do not become infertile (under standard agrotechnology conditions) and their area is limited. Due to these features, the value of agricultural lands is dependent mainly on their destination (whether already been used or might be used). The lands used for agricultural purposes are generally less expensive than other types of lands as the agricultural lands are utilized mainly in an extensive, not intensive way (Wierzycka, 1999).

Agricultural production systems constantly undergo changes and modifications. This is mainly related to the stages of agriculture development. The systems of agricultural production on the farms are consciously chosen and adopted by the farmers who take measures in order to achieve the intended production effects. This approach to agricultural lands management, affecting both organizational actions and investments, is about to improve the management efficiency. The main activities in this field include the farm area expansion and the increase of stocking rate (as regards the livestock industry), the introduction of simplified production technologies or the monocultures cultivation. These changes were aimed at improving the efficiency of farm management and the utilization of the production scale effect. At each stage of farm development, one can distinguish various farming systems, namely extensive, conventional, intensive or organic. Formerly, these systems were primarily being related to the accrued production effects. Currently, the particular emphasis is being additionally put upon the fact of the need to reduce environmental risks.

The agricultural production system, also known as the agricultural system or agrosystem, can be defined in numerous ways. As Zimny (2007) points out, there are a lot of definitions of agricultural systems. Mostly, however, agricultural system is defined as the method of agricultural land use management as far as growing plants, livestock rearing and their processing is concerned, simultaneously being subject to ecological and economic criteria (Harasim, 2006; Niewiadomski, 1993). Manteuffel (1984) states that agriculture as a system of agricultural production is considered as a farm and it functions in the form of farms.

Various divisions of agricultural systems can be distinguished both in Poland and in the whole world. These divisions are primarily being determined on the basis of production expenditures, environmental burden and the level of environmental, social and economic sustainability (Andersen et al., 2007; Blazy et al., 2009; Castel et al., 2003; Dogliotti et al., 2014; Ottaviani et al., 2003). In 2005 in Europe, as it was commissioned by the European Commission (European Commission, 2005), a report on existing agricultural production systems in the European Union was developed and published. According to the authors of this report, most EU countries apply in the majority agricultural systems (agrosystems) as follows: organic farming, integrated farming, protective agriculture, qualitative agriculture, precision farming, urban agriculture, permanent agriculture and permaculture.

Besides, in recent years in Poland there have also more and more frequently been conducted the analyses of different management systems (Krasowicz, 2009; Mądry et al., 2011; Sawa, 2000; Sawa, 2006; Walaszczyk, 2012; Wesołowski, 2007). The following division of agricultural systems is most commonly used:

- conventional agricultural production system – a system of management that is directed to providing a stable source of family income obtained owing to manifold livestock rearing and crop production, accompanied by limited fixed assets purchases or the expenditures of material and energy.

- intensive system - a way of management aimed at maximizing the income and involving high environmental risk and high material and energy expenditure.
- sustainable system – an agrosystem based on integrated production methods. The key role in this system is played by the application of internal links between the production branches as regards farming and the environment.
- extensive system – a type of management aimed at obtaining high family incomes owing to adequately large areas of selected plants cultivation (the simplification and the scale of production).

The division between intensive and extensive farms can be made based on the analysis of expenditures and the knowledge of the fact that a given farmer applies the intensive system if it reveals high expenditure of both labour and means of production per 1 ha. On the other hand, an extensive farm is characterized by low labour input and low expenditure of means of production per unit area within the agricultural land (Rychlik and Kozieradzki, 1981). Apart from the above-mentioned division, one may also distinguish a division covering three types of systems, that is industrial, sustainable and eco-friendly systems. This division is the most frequently used when debating the implementation of sustainable management systems (Krasowicz, 2009).

## 8.2. Material and methods

The materials used in this paper constitute a part of the research conducted in 2009-2010 as the element of the development project No. 12 004306 entitled "Technical and ecological modernization of selected family farms". Within the project, the researchers from four institutes and four universities studied 53 family farms from different parts of Poland (Figure 8.1) (Kurek and Wójcicki, 2011; Wójcicki and Kurek, 2011; Wójcicki and Kurek, 2012).

The group of 41 farms was divided into three farming systems sections: intensive, sustainable and conventional. The intensive system section included the farms on which occurred both crop production and livestock rearing and where the stocking rate exceeded 1.5 LU*ha-1 agricultural land, which increased the expenditure of the product of mainly the agricultural origin used for livestock feeding. The group representing sustainable production system included the farms not belonging to intensive farming group, with both plant production and livestock rearing where the balance of organic matter remained within the acceptable limits (from 0.4 to 1.5 t/ha arable land). The conventional system section covered the farms where the organic matter balance was either below or above the acceptable limits and did not meet the criteria for intensive farms. The research group did not include organic and extensive farms.

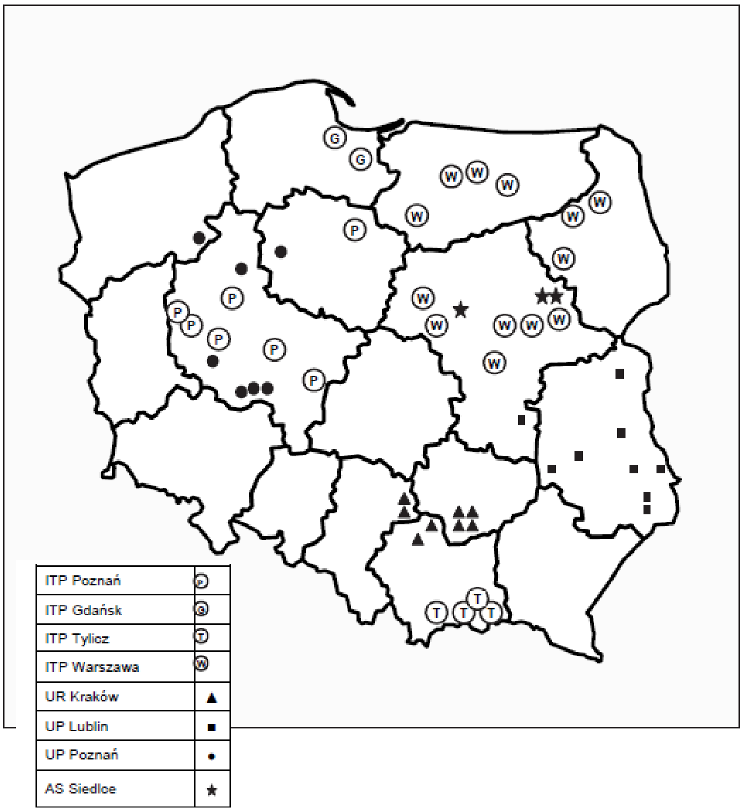


Figure 8.1. Location of family farms studied as part of a development project No. 12 004306.

Additionally, each farm as a whole was provided with the estimated value of its agricultural land. The values were estimated based on market information.

Graphic and tabular analytical techniques, basic statistical methods and the unequal N HSD test were introduced and applied in order to analyze the results of the research.

### 8.3. Results

There were 41 family farms selected for analysis. The average area of agricultural land amounted to 38.14 ha with a standard deviation of 19.76. The size of the areas of agricultural land on those farms was several times bigger than the average national one in 2010, amounting to 7.92 ha (GUS, 2011). In 2009 the size of the smallest farm's agricultural land amounted to 8.58 ha and the size of the largest one equalled 85.00 ha. The structure of agricultural land of each farm included arable land. Cereal with over 52% share dominated in the structure covering crop production (Figure 8.2). Nearly 25% of the structure of crop comprised meadows and pastures which along with maize for forage and silage, forage and silage legumes and crops for roughage made up over 40% of the agricultural land. The smallest group constituted crops classified as other such as fruit, berry orchards and vegetables grown in the field.

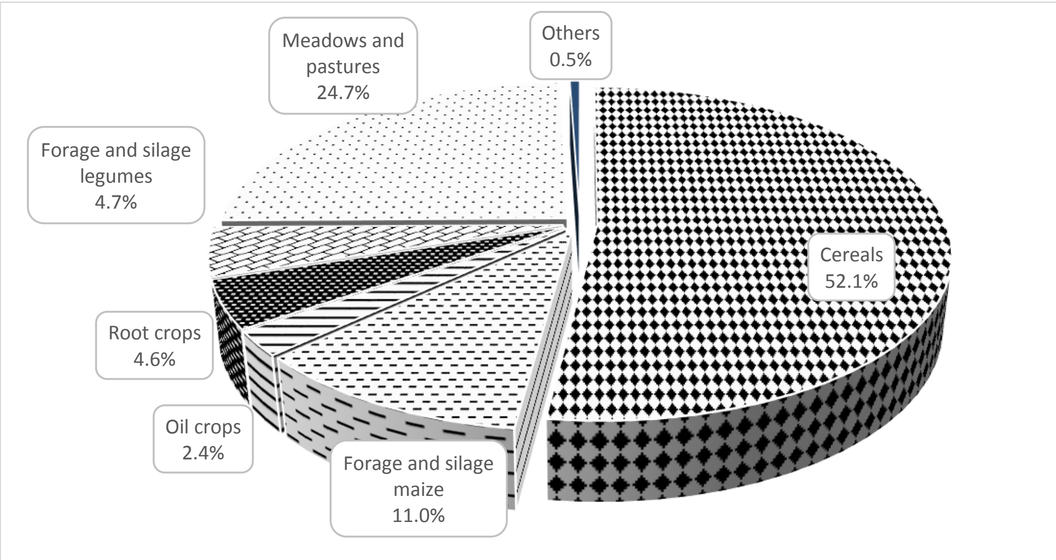


Figure 8.2. The structure of crop within the research group of farms

Within the analysed group, there were 23 conventional farms, 7 intensive and 11 sustainable farms. The values of agricultural lands varied significantly. The average value among conventional farms respectively amounted to 1,241,900 PLN, among intensive farms – 819,888 PLN and among sustainable farms 703,446 PLN.

The average areas of agricultural land in conventional and sustainable farms were similar. The farms with intensive agricultural production system were almost 9 ha smaller than conventional farms and nearly 7 ha smaller than sustainable farms.

Besides, the average value of the balance of organic matter among intensive and sustainable farms remained within the acceptable limits, whereas conventional farms revealed lower value of the rate.

Average stocking rate on intensive farms was very high and exceeded the acceptable limit recommended in the Code of Good Agricultural Practice. Regarding the level of mechanization, it remained approximate within the study groups.

The intensity of the organization of production on conventional farms was over two times lower than on intensive farms. The values of Gross Margin per 1 ha regarding conventional and sustainable farms were similar. In the case of intensive farms, the value of Gross Margin was almost twofold higher than conventional farms. Moreover, the rate of commodity production regarding cereal units per 1 ha was the highest on intensive farms (Table 8.1).

Table 8.1. General characteristics of studied farms

| **Specification** | **Agricultural production system** | | |
|---|---|---|---|
| | Conventional | Intensive | Sustainable |
| Number of farms | 23 | 7 | 11 |
| Value of agricultural land (PLN) | 1,241,900 | 819,888 | 703,446 |
| Area of agricultural land (ha) | 40.12 | 31.55 | 38.21 |
| Balance of organic matter (t/ha arable land) | 0.33 | 1.36 | 0.77 |
| Stocking rate (LU/ha AL) | 0.7 | 2.3 | 1.1 |
| Degree of mechanization of work process (%)* | 68 | 67 | 72 |
| Intensity of organization production (point) | 391 | 847 | 494 |
| Gross Margin (thousands PLN/ha AL) | 4,38 | 8,03 | 4,55 |
| Commodity production net (CU/ha AL) | 48 | 92 | 58 |

** Described by J. Sawa (see page 38)*

The highest value of 1 ha of agricultural land was reported among the intensive farms and the lowest one among the sustainable ones (Figure 8.3). The average value of 1 ha of agricultural land on intensive farms equalled 39,358 PLN, on conventional farms it was 20,438 PLN and on sustainable farms it amounted to 16,807 PLN.

Along with the increase in the area of farms with intensive production system, the value of 1 ha of agricultural land also increased. Within the group of farms with conventional production system, the rates of value of 1 ha of agricultural land were very diverse.

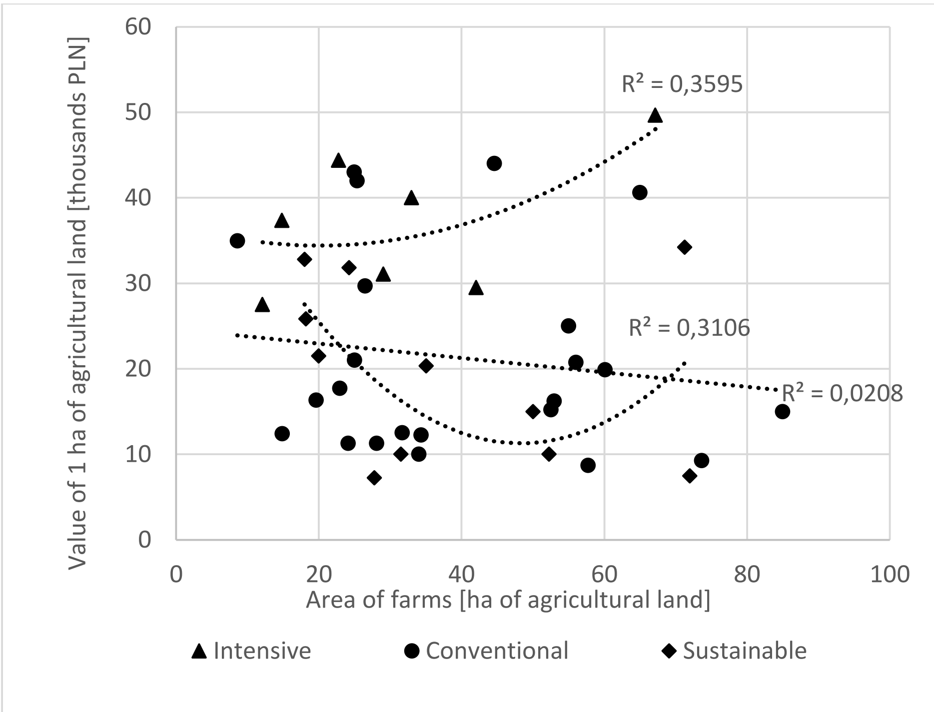


Figure 8.3. The value of 1 ha of agricultural land in studied farms divided into agricultural production systems

Figure 8.4 shows the spread of the variables within the groups of farms. The highest median characterized the farms with intensive agricultural system. The statistical analysis for the unequal N HSD test among the values of agricultural land in each group revealed no significant differences. The analysis of the differences between the values of 1 ha of agricultural land in each group showed that the value of 1 ha of agricultural land in farms with intensive production system differs substantially from the value of 1 ha of agricultural land in case of conventional farms and sustainable ones. However, no significant differences were observed regarding the conventional and sustainable systems.

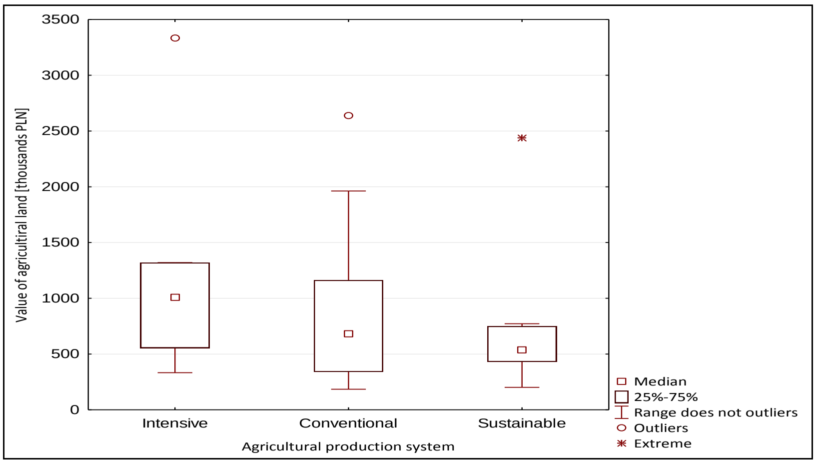


Figure 8.4. The spread of 1 ha agricultural land values in the individual agricultural systems

## 8.4. Conclusions

The analysed farms represented three systems of agricultural production. The value of agricultural lands among the groups varied considerably. These differences can be identified based on the collected data and the data analyses. The smallest value of agricultural lands occurred among sustainable farms and the largest one among the conventional farms.

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## KEYWORDS AND TOPICS INDEX

SUSTAINABLE AGRICULTURE - POLAND AND PORTUGAL

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