TYPOLOGY OF FARMS AND REGIONS IN EU STATES ASSESSING THE IMPACTS OF PRECISION FARMING-TECHNOLOGIES

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ABSTRACT

This investigation aims in an estimation of potentials for the use of Precision Farming (PF) on regional scale in Europe. A potential analysis was conducted with the aid of literature and Europe-wide statistical data resulting in PF-potentials.

Literature, which investigates the regional distribution of Precision Farming, is in the main focussing on example farms and regions or is based on the national adoption rates of PF. The literature review reveals that the north and west of Europe is more in PF-use than the south and east. Countries, which currently have in literature mentioned appreciable adoption rates of PF, are Denmark, Sweden, Germany and the United Kingdom. The Czech Republic, the Netherlands and France follow the first group in terms of use of this technology. Field heterogeneity, management intensity, farm size, cereals and vegetables are named as important driving forces adopting PF.

Following rules were derived: the more cropland, the more cereals, the more hectares per worker and the more economic powerful a region, the higher the potential for the use of Precision Farming. Based on these prerequisites a potential analysis was conducted with the help of following five indicators: (1) cropland / total area [%], (2) farms with cropland / all farms [%], (3) cropland / farms with cropland [ha], (4) farms > 16 European Size Units (ESU) / all farms [%] and (5) farmland / worker [ha/worker].

The conducted potential analysis considering the above listed indicators results in four classes of PF-potentials: very high, high, medium and low. The very high potential is focussing on the central parts of Western Europe, especially the north half of France, the east coast of England and Scotland, south Sweden, Denmark, the north and east of Germany, a few regions in the Netherlands and Belgium, one region in the Czech Republic and one in Spain. The high potential is also focussing on the countries in the north and west, while the medium and low potential is predominantly located in the periphery of Europe and in the new member states of central and east Europe.

Keywords: Precision Farming, potential analysis, EU-project “FutureFarm”

INTRODUCTION - PRECISION FARMING IN THE EU

PF is the “management of spatial and temporal variability at a sub-field level to improve economic returns and reduce environmental impacts. This can be achieved by using appropriate technologies within a coherent management structure” (Pedersen et al., 2004). The usage of Precision Farming-Technologies (PFT) is supposed to lead to a more efficient agricultural production process resulting in higher profitability. PF improves in average first the returns and economical profitability and second reduce environmental impacts for a more sustainable agriculture (Arnholt, 2001, Deutscher Bundestag, 2006, Pedersen, 2003, Fountas, 2005, Gemtos et al., 2002). Hence, PF embraces a wide range of different technologies for an optimized agriculture considering the huge amount of different management decisions and operations. Clearly, the segmentation of fields in small units or sub-fields with different applications would be impossible, if the agricultural processes could not be automated via PFT (Sylvester-Bradley, 1999).

Therefore, the farmers within the EU need new facilities to become worldwide competitive, in which PF is one possibility building an economic viable agriculture. The active EU policy “calls for reduction in import duties and export subsidies” (McBratney et al., 2005) generating continuously increasing global-market competitiveness for European farmers.

Even though PF is an agriculture for all segments of farming this study is focussing on crop production, because information are mainly based on and most technologies are market-ready and used in crops, especially cereals. Grassland and livestock farming are not being considered.

The PF-adoption has slowed in recent years on global scale compared to the mid and late 1990s (Griffin and Lowenberg-DeBoer, 2005, Schneider and Wagner, 2006, Kutter et al., 2009). “Adoption of [PF] has been less than expected, in part because it has been difficult to quantify benefits” (Fountas, 2005). The profitability and adoption rate of PF are site-specific on all regional scales (Griffin and Lowenberg-DeBoer, 2005). “The technologies which come to the market in an incomplete form may have long adoption periods with many fluctuations. PF adoption is similar to the adoption of motorised mechanisation that took a long time to penetrate the agricultural market” (Lowenberg-DeBoer, 1998 In: Pedersen, 2004). Detailed quantifications of PF-adoptions are at a holistic approach challenging, because it includes non-quantifiable benefits for environment, food-safety and farming in general (Reichardt and Jürgens, 2008b).

The benefits of PF are generally dividable in the economical and the environmental ones (Brase, 2006). Although quantifications of costs and benefits of PF are hard as universal valid statements due to heterogeneous distributions of impact factors “several studies demonstrate the economic and ecological benefits of PF tools over conventional techniques” (Kutter, 2009).

Overcoming the emerging problems at the beginning, which the farmers have to endure, most of them are being satisfied and would recommend the new technologies to others (Deutscher Bundestag, 2003, Reichardt and Jürgens, 2008a, Reichardt and Jürgens, 2008b, Reichardt et al., 2009, Hüter and Klöble, 2007). The farmers are getting more information and knowledge about and benefit out of their fields by following items: decreasing inputs, more efficient use of inputs in general, especially of fertilizers and pesticides, and increasing outputs (yield, money).

Farmers' main incentives are caused by more information about their fields and financial benefits with the economic profit as the major one. As mentioned before most of the users are satisfied with PF-Technologies and this is mainly resulting due to lower input, ease of work and better quality in farm management. Moreover, simplified documentation is an important item, because the documentation in agriculture will become a more and more important sector for traceability within the food chain and for the obligated burden of proof. The most important incentive for farmers investing in PFT is the higher monetary return.

In terms of the environmental scale PF can lead to a reduced input of matters and thus to a reduced impact on natural resources (Brase, 2006). "Sustainability is the concept of balancing environment and economic needs in order to maintain our natural resources and business. Technology has the ability to incorporate economic and environmental parameters to make a balanced decision, which creates sustainability" (Brase, 2006). The PF is named to have the ability to provide the technology for the environment friendly agriculture of the future (Auernhammer, 2001).

There are still some obstacles, which hinder farmers to invest in PF for a wider distribution of new technologies (Fountas, 2003, Deutscher Bundestag, 2006, Kutter et al., 2009, Reichardt et al., 2009, Reichardt and Jürgens, 2007a, Reichardt and Jürgens, 2008a, Zhang et al., 2002, Pedersen et al., 2003). One big item is the low trust in common internet-based data storage, which makes private storage necessary. Besides the farmers' reluctance of internet-based storage the required high investment and learning costs, time consumption, analysis and transfer of data, malfunction of GPS-reception and missing interoperability of different PF-systems and devices avoid many farmers from the new technologies. Data misuse, overregulation and software incompatibility are three important aspects, which are often mentioned by farmers for their reluctance towards PF. Lower prices, better and more comprehensive information flows and financial supports are the three main prerequisites for a wider application of PF. Other important topics are the usage and information winning out of the abundant amount of data. PF-Technologies "now [have] the ability to produce data about soils and crops at sub metre level across the whole field but the capability to use this data is very limited until suitable systems are developed" (Blackmore et al, 2002 In: Gemtos et al, 2002). A lot of farmers who use PF-Technologies are overburdened by Precision Farming's complexity (Reichardt, 2009).

Mainly the larger farm holdings are using PFT, but nowadays more and more smaller farms are getting in touch with PF (Reichardt and Jürgens, 2008a, Jürgens, 2006). Farmers wish lower investment costs, better or even complete interoperability of systems, user-friendly software, good survey of data, automatism techniques and a few farmers also mention internet-based data storage and information flow as important improvements for a higher level of acceptance. Moreover, a few studies consider small autonomous machines (robotics) as more efficient than the traditional large tractors, especially on challenging fields, for example in vegetables or on fields with major slopes (Blackmore, 2006). The embedded intelligence techniques within the small scaled robots can minimize or even replace the over-application of chemicals, as the PF-Technologies for the large tractors also do, but the robotic systems can also minimize the high use of energy and produces only low soil compaction according to moisture issues, like water-logging.

LITERATURE REVIEW – PF-ADOPTION IN EU

Several studies investigate the adoption rates, but mainly nationwide, which makes comparisons on the European level in time and space quite difficult. "The natural tendency of scientists to assume that what they consider to be a good product of research will be enthusiastically embraced by potential users has proved to be naive. Adoption of any given technique in practice requires much support, explanation and nurture" (McBratney, 2005). The additional costs and time, which are needed at the beginning, hinder many farmers to adopt some kind of PFT. Besides, the use of PF-Technologies does not necessarily lead to a cheaper and more efficient production process in each case (Schneider and Wagner, 2008). Nevertheless, "the past two decades have seen significant progress in the application of the principles of precision agriculture to improve the production quality of a whole range of crops, especially higher value vegetables" (Godwin, 2007), although the question of cost and benefit relation of the relatively new technology PF could not been answered up to date because of flexible heterogeneity in time and space (Schneider and Wagner, 2006). "There is no clear answer whether there is any economical potential in using [PF]" (Schneider and Wagner, 2006) as some techniques have not reached the stage to assess the benefits in detail (Pedersen, 2003).

Since a few decades the European agriculture has been characterizing by increasing sizes of farms, fields and equipment together with lower input of manpower leading to higher efficiency in economy (Blackmore, 2006). Nevertheless, most of the European agriculture is, in contrast to the in parts domination of large farm companies overseas, still on small-scale and still predominantly within the traditional family structure avoiding rapid changes. Therefore the European agriculture is not competitive in terms of the economies of scale, but it offers other goals considering social and ecological sustainability, like the protection of historical grown cultural landscapes.

PFT are providing opportunities for an economic more profitable agriculture inside Europe. The adoption of PF within the EU varies strongly. While the northern parts of Europe have increased in using PF on similar terms like the USA, Australia and some parts of South America, southern Europe is a relatively new region for PF-Technologies or in some regions even not connected to PF (Karydas, 2003). The European Union in total is having the highest adoption rate worldwide together with North America (Blackmore et al., 2006, Pedersen, 2003). Furthermore, the usage of PF-Technologies is mainly adopted by farmers with some hundred ha. Just a small number of farms are of this size, because the average farm size in Europe is less than 20 hectares.

The EU-countries, which are named in literature according to noticeable PF adoption rates, are Denmark, Germany, Sweden and the United Kingdom. France, the Netherlands and Czech Republic follow below the group of European PF-leaders. In general Northwest Europe has larger adoption rates of PF than the Mediterranean region and the new EU states in Central and Eastern Europe (Gemtos, 2002, Karydas, 2003).

Although EU-wide comparisons between different surveys and countries are not being meaningful with the help of literature some trends are obvious: The countries in north and west of Europe are currently being stronger involved in the PF-adoption than the countries in the south and east of Europe, which is an overall trend. The highest adoption rates are mentioned for Denmark, the United Kingdom and Germany.

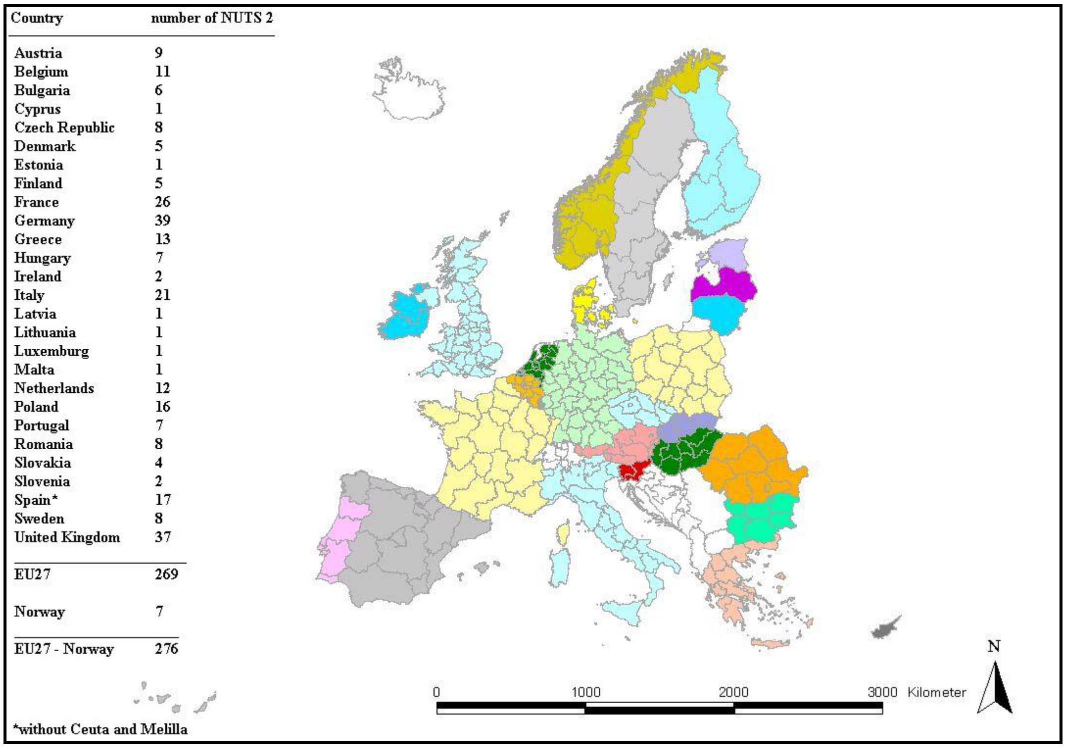
The investigated publications mention some factors, which show a high potential for PF: field heterogeneity, management intensity, farm size, cereals and vegetables. These five factors are named to be important for a profitable use of PF. As the results from the literature search do not provide Europe-wide information regarding the current PF-adoption rates, a potential analysis was conducted in consideration of above mentioned factors. The conducted potential analysis of European agriculture helps to assess the PF-potential on sub-national level in Europe and show a way for a regionalized approach with the aid of public available statistics.

MATERIALS AND METHODS

The regional distribution of the potential use of Precision Farming was generated with the aid of an analysis for the 27 member states of the European Union and Norway. The source of used statistical data is EUROSTAT providing agricultural information on regional scales from national to regional level. The potential analysis of European agriculture was accomplished to assess the PF-potential on sub-national level in Europe and to show an opportunity for a regionalized approach with the aid of public available statistics.

NUTS (Nomenclature of territorial units for statistics) are administration units, which were implemented for statistical comparisons between regions in Europe (EUROSTAT, 2010). EUROSTAT statistics are available on NUTS-level zero, one, two and three, which consider different administration levels from national (NUTS 0) to smaller regions (NUTS 3).

As the data are for all European regions available on the NUTS level 2 this level was used, which is defined with a number of 800,000 until three million inhabitants per NUTS 2-region (Map 1). While they are homogeneously in terms of the number of inhabitants, they differ apparently in size and of course in agricultural items. On larger scale (smaller regions), NUTS 3, data are not available for all regions in Europe. Therefore we use the as large-scaled as possible unit NUTS 2 was used for the statistical approach avoiding a lack of data.



Country	number of NUTS 2
Austria	9
Belgium	11
Bulgaria	6
Cyprus	1
Czech Republic	8
Denmark	5
Estonia	1
Finland	5
France	26
Germany	39
Greece	13
Hungary	7
Ireland	2
Italy	21
Latvia	1
Lithuania	1
Luxemburg	1
Malta	1
Netherlands	12
Poland	16
Portugal	7
Romania	8
Slovakia	4
Slovenia	2
Spain*	17
Sweden	8
United Kingdom	37
EU27	269
Norway	7
EU27 - Norway	276

*without Ceuta and Melilla

Map 1. Number of NUTS 2-regions in EU-27 and Norway

Required indicators have to be suitable to reflect the potential of PF as precise as possible. With the aid of literature these important **rules** have been derived: the more cropland, the more cereals, the more hectares per worker as a rule for the management intensity and the more economic powerful a region, the higher the PF-potential.

The distribution of PF is mainly determined by the profitability on farm-level (Deutscher Bundestag, 2006, Reichardt, 2009). PF-adoption has been fastest where labour “is costly but land and capital are relatively less costly” (Swinton and Lowenberg-DeBoer, 2001). Important influencing factors are field heterogeneity, management intensity and farm size. The more heterogeneity exists and the higher the management intensities are the more profitable is the PF-use. The larger the farm, the more profitable is the PF-investment in general, because the probability of significant changing conditions is growing in size and costs are allocated on more hectares. It is uneasy to determine a size, from which on the use of PFT is generally profitable or on the contrary not. The minimum size for a profitable use is changing in terms of a lot of different issues, like location, soil, climate, farm structure, etc. PF is mainly “geared toward large-scale farming, increasing its existing production advantages” (Auernhammer, 2001), while the most regions around the world and within the EU are dominated by farms with comparable small sizes (Auernhammer, 2001, Knight et al., 2009, Kutter, 2009, Hüter and Klöble, 2007, Pedersen, 2003, Markinos et al., 2005). Smaller farms do mainly not have the ability in terms of manpower, time and money for PF-adoption (Reichardt, 2009, Deutscher Bundestag, 2003). Nevertheless, a Belgium survey pointed that average field sizes of 1.7 ha can also be heterogeneous enough for site-specific application (Deutscher Bundestag, 2006). These small sizes of farms and fields need new concepts for the PF-adoption, like the so called “virtual land consolidation” (Auernhammer, 2001), “transborder farming systems” (Auernhammer, 2001) or “fleet management” (Auernhammer, 2001). Contractors are assumed to be a major driving force behind the adoption of PF, especially in areas with smaller sized farms (Kutter et al., 2009). Outsourcing PF tasks to contractors or larger farms is an opportunity for smaller farms to take part in this technology. Besides, the advisory services are also believed to have an important impact on the adoption and further development of PF (Pedersen et al., 2004, Reichardt et al., 2009). Additionally to the farm sizes, the grown crops are important for the PF-distribution. The intensive husbandry, especially of cereals and vegetables, is mainly linked to PF (Hüter and Klöble, 2007, Blackmore, 2006).

As mentioned in the literature review some **factors** represent high potentials for PF: field heterogeneity, management intensity, farm size, cereals and vegetables. These five factors are named to be important for a profitable use of PF (see above). Keeping the derived rules and factors in mind some **indicators** were generated in consideration of available statistical data. The five indicators were investigated in terms of correlations, but no strong or very strong correlations between the indicators revealed. The chosen indicator **(1) cropland / total area [%]** offers information about the distribution of farming in general as a land use-related indicator. The further four indicators **(2) proportion of farms with cropland / all farms [%]**, **(3) cropland / farms with cropland [ha]** as an indicator for the average cropland size of farms with cropland, **(4) proportion of farms with more than 16 European Size Units (ESU) / all farms [%]** and **(5) farmland / worker [ha/worker]** as an indicator for the above mentioned factor management intensity are all predominantly farm-related.

Indicator (4) considers the economy of farms and is related to the European Size Unit (ESU). One ESU represents 1,200 € standard gross margin and is used to express the economic size of farms. 16 ESU are the limit for full-time farms in Belgium, Germany, the Netherlands and the United Kingdom, while the other EU-countries are currently having lower ESU-borders representing full-time farming, e.g. Denmark, Slovakia 8 ESU, Spain 4 ESU, Poland, Portugal 2 ESU and the latest new member states of the EU Romania and Bulgaria with 1 ESU. The farms > 16 ESU per all farms [%] display the ratio of economic large farms to all farms in a region, because especially these farms are linked to PF due to higher assets for investments in new technologies. Indicator (5) farmland / worker depicts the management intensity within the NUTS 2-regions. It is determined that the potential of PF increases with a growing number of hectares being farmed by one worker.

As the data for the two regions Inner London (UKI1) and Bucharest (RO32) are not available for all five indicators the potential analysis was carried out without these two city regions. Each of the in total 274 considered NUTS 2-regions in EU-27 plus Norway were ranked for each indicator from 1 until 274. After ranking all regions for the five selected single indicators these single rankings were aggregated to a total ranking. Finally, the total rankings were divided in four categories of potentials: very high, high, medium and low (s. Chart 1).

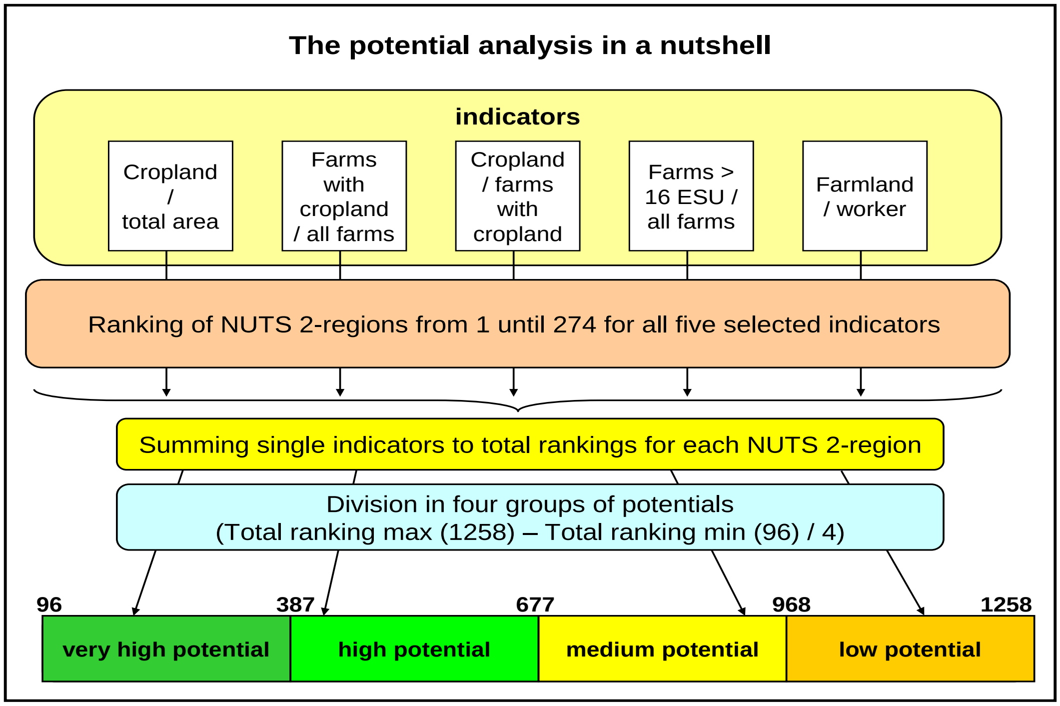


Chart 1. The potential analysis in a nutshell

The single regions were calculated with the addition of the five single indicators using the lowest total ranking (total ranking min: 96) and the highest total ranking (total ranking max: 1258) to define borders for the four potential degrees very high, high, medium and low. The spread between these two extreme regions representing the very highest and very lowest PF-potentials was divided in four equal sized segments. The regions with very high potential cover a range from value 96 until 387, the high potential the range from 387 until 677, the medium potential the range from 677 until 968 and the regions with a total ranking higher than 968 get a low potential. Hence, 44 regions out of 274 NUTS 2-regions result in a very high potential, 91 in a high, 92 in a medium and 47 in a low potential.

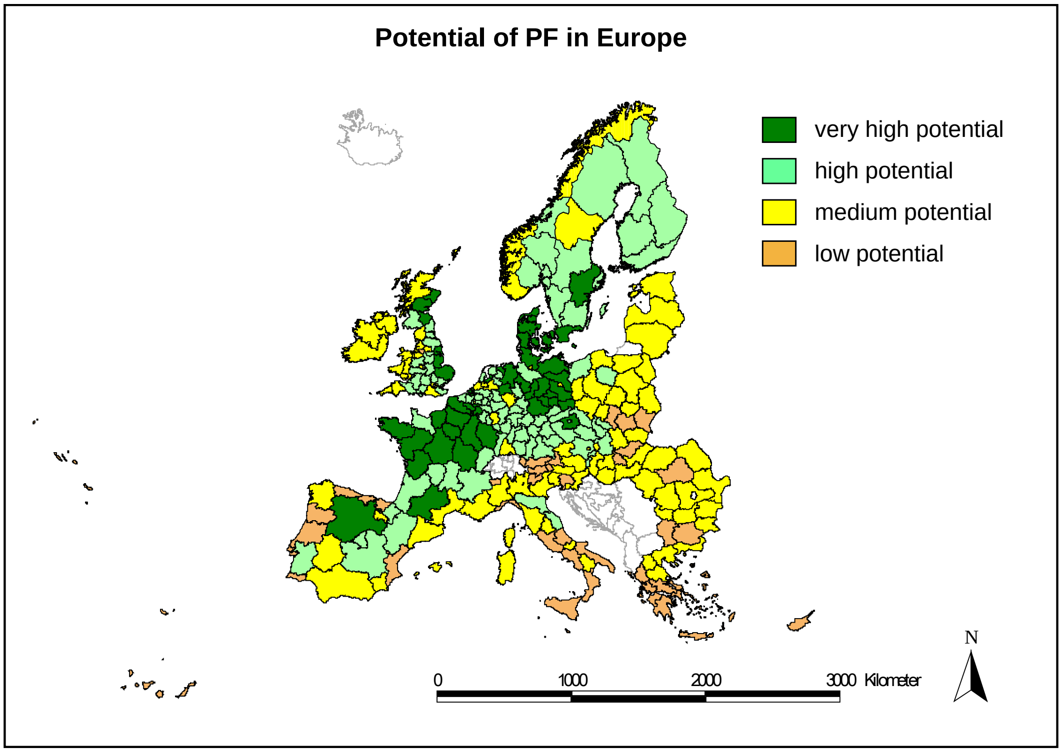
RESULTS AND DISCUSSION OF POTENTIAL ANALYSIS

The focus on cropland farming is due to the main use of market-ready and available devices for cropland in current times. The results won with the help of the above presented analysis are only valid for cropland and do not consider any possible developments of PFT on grassland and in livestock farming. Furthermore, the results show potentials for NUTS 2-regions, in which agricultural management conditions definitely change on smaller scales, and have to be seen as averaged potentials for regions.

Map 2 shows the results of the potential analysis considering the five indicators (1) cropland / total area, (2) proportion of farms with cropland / all farms, (3) cropland / farms with cropland, (4) proportion of farms with more than 16 ESU / all farms and (5) farmland / worker. All five indicators are responsible for one fifth of the final result, therefore each indicator has the same impact and importance for a very high, high, medium or low potential.

As presented in Map 2 the very high potential is focussing on the central parts of Western Europe. Regions with a very high potential are concentrating on the north of France, a few NUTS 2-regions in the Netherlands, Belgium and the United Kingdom, as well as some regions in the north and east of Germany, the south of Sweden and all five NUTS 2-regions in Denmark. Furthermore, one region in Spain and one in the Czech Republic result in a very high potential for the use of PF valued at this potential analysis.

The high potentials are also concentrating on the west and north of Europe, especially Scandinavia, the United Kingdom, Germany, the Netherlands, Belgium, France, Spain and the Czech Republic. The Czech Republic with seven NUTS 2-regions having a high potential is the country of the new EU-enlargements, which has by far the highest PF-potential of all new EU member states of Central and Eastern Europe. Furthermore, Luxembourg, two regions in Italy, two in Austria, two in Poland, one region in Portugal and also one in Slovakia result in the category high potential. Hence the highest potentials are on national level in Denmark, Germany, the United Kingdom and France followed by Sweden, Finland, the Netherlands, Belgium, Spain and the Czech Republic. This distribution of the potential analysis within the European Union is comparable to the results from literature, which mentions highest adoption and use of PF mainly for Denmark, the United Kingdom, Germany and Sweden. The Czech Republic, France and the Netherlands are also named to have considerable amounts of PFT in literature, which also fits to the conducted potential analysis.



Map 2. Potential of PF in Europe

The medium and low potential is concentrating on the one hand on the western periphery of Europe, the Atlantic coast areas of Scandinavia, Ireland, Portugal and Spain as well as the Mediterranean region (Spain, France, Italy, Greece) and on the other hand most of the new member states in central and eastern parts of Europe with the exception of a few regions in the Czech Republic, Slovakia and Poland.

Eleven out of the in total 274 calculated NUTS 2-regions in EU-27 and Norway outcome in a very high potential for all five single indicators. These are the four of five Danish NUTS 2-regions Sjaelland, Syddanmark, Midjylland and Nordjylland, the four French regions Ile de France, Picardie, Centre and Nord – Pas-de-Calais, the German regions Braunschweig and Hannover and Provinz Brabant Wallon in Belgium. But there are also some regions resulting in a very high potential, which have for a single indicator just a medium potential, but for the remaining four indicators high or even very high results.

Some regions from the low potential group have for single indicators high potentials and two regions with summarized low PF-potential are grouped for two indicators into high level. These two regions are Malta and Malopolskie in Poland. The two indicators, which are grouped as high for Malta and Malopolskie, are the first (cropland / total area) and second one (farms with cropland / all farms), while the following three indicators cropland / farms with cropland, farms > 16 ESU / all farms and farmland / worker are grouped in the low potential class.

Two regions in Norway, two in Romania and five Polish regions are classified in two of the five indicators with a very high potential, but in the summarized ranking of potentials listed in the third group representing a medium PF-potential. These seven Polish and Romanian regions have – comparable to the above mentioned low potential region Malopolskie in Poland – good results for the first two indicators cropland / total area and farms with cropland / all farms with very high potentials. Like in Malopolskie the other three indicators considering the farm size, the economy and the management intensity downgrade the PF-potential to a medium level. Poland and Romania together with some other new member states of central and east Europe have a high land potential for modern technologies in agriculture, but economic and other farm-related characteristics do currently inhibit higher potentials in this regions.

The results of the above presented and conducted potential analysis depicting the potential of PF for regions on the level NUTS 2 are comparable to the hints won with the aid of literature. The countries with highest adoption rates in literature are Denmark, Sweden, the United Kingdom and Germany as well as to some proportion France, the Netherlands and the Czech Republic. The regions with mainly very high and high potentials using PF-Technologies are also concentrating on the countries in the north and west of Europe. The disadvantages for the use of PF in the periphery, like the Atlantic and Mediterranean coasts, are low rates of cropland, small farms and fields as well as being economic not very powerful. Regions along the shore are for most indicators and most regions – Norway has to be seen as an exception – worse classified than the interior regions. Furthermore, the most regions of the new member states in Central and Eastern

Europe result in medium or even low PF-potentials. Just a few regions in Poland, Slovakia and especially the Czech Republic have a high and one Czech NUTS 2-region even a very high PF-potential. The Czech Republic has in average comparable large farms and lots of cropland. Although the economic indicator farms > 16 ESU per all farms downgrades the Czech regions to some extent in terms of the PF-potential, the before mentioned characteristics of Czech agriculture cause the very high and high potentials there.

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