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Potentials of biomass production in the region of Central Macedonia

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Abstract

This dissertation was written as part of the MSc in in Environmental Management and Sustainability at the International Hellenic University.

The aim of the master thesis is to examine the potentials of biomass production in the Region of Central Macedonia (RCM). For this reason, a model of Multi-Criteria Analysis (MCDA) with ELECTRE III method is developed, with the construction of outranking relations. The aim is to compare in a comprehensive way each pair of action, in our case the regional units of the RCM, in order to satisfy the main goal which is to rank the seven regional units as regards their biomass production. The final goal is to select the optimal crop plan between the seven regional units as a pilot case for biomass production. In the case of ELECTRE III multicriteria model, we used several conflicting criteria such as the farm income, the biomass production from crop residues, the variable costs, the production of thermal energy, the production of electrical energy, and finally thermal energy and electrical energy. Alongside a technical and economic analysis of the study area is conducted for the existent crop plans of each regional unit. The main findings of the master thesis are the biomass production for the seven regional units of the region of Central Macedonia and the optimal crop plan for producing biomass from agricultural residues. The results show that crop plans with cereals and arable crops have better results than crop plans with fruit trees and other crops.

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Keywords: Biomass production, Multicriteria model, Electre III

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Preface

This master thesis examines the potentials of biomass production in the Region of Central Macedonia (RCM). The master thesis is organised in five chapters.

The first chapter motivates the readers in the subject of the master thesis. At first, a brief description of the problem is presented with the use of the latest researches. The aim of the master thesis and the main research questions follows.

The second chapter, includes the literature review both for the biomass production from crop residues, and for the ELECTRE III multcriteria method.

In the third chapter, the methodology of the ELECTRE III multicriteria model is presented with all the necessary mathematical equations. Also, the chapter includes the presentation of the case study area and the calculation of the main environmental and economic indicators that will be used as criteria for the ranking of the regional units of the Central Macedonia.

The forth chapter, presents the results of the analysis from the implementation of the ELECTRE III multicriteria model. Also, the main results are presented as regards the potential biomass production, the electrical and thermal energy produced by crop residues and the results for the selected economic and environmental criteria. Finally, the main results are the ranking of the seven regional units of the region of Central Macedonia.

The fifth and final chapter, contains the concluding remarks.

Contents

Introduction

The new challenges to find new sustainable energy sources, independent from the non-renewable (eg oil, gas, coal) and the challenges to reduce the CO_2 emissions are some of the most important goals of European Union environmental policy (EC, 2005, EC, 2010). The biomass production from agricultural residues enhances the role of agriculture in the creation of new sustainable energy sources and connects directly with rural development policy (Rosillo-Calle, 2003). This can be achieved by cultivating crops in agro-energy districts with high values of agricultural residues. One of the main European Union's objectives for the programming period 2014-2020 is the establishment of agro-energy districts and the increase of energy production from renewable sources. Almost two thirds of renewable energy sources, in the European Union (EU), origin from biomass, including agri-food waste (Fischer and Schrattenholzer, 2001). As biomass sources are considered energy crops, agricultural crop residues, animals waste and forest residues. The use of crop residues and waste is already at a high level in several European countries (van Dam et al., 2007), but the use of energy crops has still controversial aspects.

The energy crops cultivations and their conversion into bio-fuels has increased considerably over the last 15 years, through research on the production of thermal, electrical energy (Guo et al., 2015). The increase of biomass use in European Union (EU) except of giving the opportunity to produce another type of power also creates new job positions, leads to decrease of the CO_2 emissions and support the development of economy (Manos et al., 2014a). There are also many advantages that the biomass use creates with main goal the decrease of negative impacts to the environment and the maximization of the sustainability benefits. The main advantages of the use biomass in energy production is to reduce air pollution, to support decentralization with the creation of jobs in less favoured agricultural areas, to attract new investments, to encourage rural innovation and to enhance farm income, while electrical production processes are more environmentally friendly (Fantozzi et al., 2014a). Also, in this financial crisis period, the use of agricultural residues and the energy efficient crops can contribute to better management of production and enhance competitiveness. The disadvantages are focus mainly on the difficulties in collection, storage, transport and in the high humidity of agricultural residues and the variable energy efficiency.

The intentions of European Union to increase the production of biomass in agro-energy districts, led us to examine the potentials of biomass production in the region of Central Macedonia. The region of Central Macedonia is one of the largest and unexploited biomass resources whether it comes from energy crops or residues of other crops. As mentioned before, European Directive considered as biomass energy crops, the timber products, the agricultural products, agri-food waste and urban solid waste. This master thesis will deal with the potential biomass production from agricultural residues. Central Macedonia includes seven regional units, the regional unit of Thessaloniki, Imathia, Kilkis, Pella, Pieria, Serres and Chalkidiki. According to the biomass potential maps of the National Information System for Energy (2016), the region of Central Macedonia has the largest reserves of biomass from agricultural residues throughout Greece. Creating conditions for economic, social and environmental development in the primary sector of Central Macedonia by developing new activities, is a way for Greece to overcome the financial crisis. But this opportunity will remain unexploited or undeveloped without a coordinated plan.

One of the main objectives of the study will be the calculation of various factors and indicators (such as farm income, potential thermal energy, etc). Alongside, the selection of the optimal crop plan between the crop plans of the seven regional units of the Central Macedonia region is the main goal. Finally, a comparison between the crop plans and the economic and environmental indicators can be achieved. Analytically, in order to find the potentials of biomass production in the region of Central Macedonia we will use the residues from crops cultivated in this region. Then, we will calculate the potential electrical and thermal energy that will be produced from these residues. The main goal of the master thesis, the selection of the optimal crop plan between the crop plans of the seven regional units of the Central Macedonia region, which can achieve the optimal bio-energy production system using agricultural residues and energy crops, will be achieved by applying the tool of ELECTRE III (ELimination and Et Choix Traduisant la REalite). With the tool of ELECTRE III multicriteria model, we will rank the seven regional units of the Central Macedonia (Thessaloniki, Imathia, Kilkis, Pella, Pieria, Serres and Chalkidiki) with the use of a set of criteria regarding economic and environmental aspects. For this reason, a Multi-Criteria Analysis (MCDA) model will be developed, with the construction of outranking relations between the crop plans of the seven regional units. In the next steps, ELECTRE III multicriteria model will compare in a comprehensive way each pair of crop plans and will rank them with the use of eight conflicting criteria. The three of them are economic criteria (gross margin, income and variable cost) and the five of them are environmental criteria (biomass production, production of thermal energy, production of electrical energy, thermal energy and electrical energy). The final result will be the ranking of the seven regional units according to their potential production of biomass from crop residues.

The research questions to be answered are summarized as follows:

• Which crops can produce high levels of biomass?

• What combination of crop management (cereals, fruits trees, arable crops, energy crops, other crops etc.) will produce the highest levels of biomass?

• Which crop plan can achieve the farmers' goal of maximisation of gross margin and the environmental goal of maximisation of biomass production?

Literature Review

This section will include a short literature review both for the biomass production from crop residues and for the ELECTRE III multicriteria model. The results of the literature review showed that many researchers in the last decade deal with the biomass production from crop residues. The increasing concern for biomass production is the result of the new policies that the European Union introduced in the last twenty years.

Biomass

The main agricultural policy is the Common Agricultural Policy (CAP). CAP has set a series of environmental measures known as Agrienvironmental Schemes. These measures conditions should be satisfied by the farmers, in order to be eligible for receiving subsidies for their cultivations. The new CAP framework for the 2014–2020 programming period reinforces the environmental conservation agenda (Vlontzos et al., 2014). According to Vlontzos et al (2014) the impact of these policy interventions has effects on both the energy and environmental efficiency of primary sectors of EU member states.

Also one of the main objectives of the Horizon 2020 program is the creation of competitive industries based on sustainable techniques (EC, 2015). The contribution of biomass utilization industries from agricultural residues and in particular in Southern Europe presented in several research papers (Fantozzi et al., 2014b, Manos et al., 2014b). In this way given an incentive to farmers to maintain agricultural residues, a new form of bio-energy, agro-energy regions grow, diminish the effects of climate change and created a sustainable economic model formed (Tziolas et al., 2016). In comparison with the residues management, the need for renewable energy sources worldwide can be met successfully by more than 50% with parallel use of energy crops (Maity, 2015).

Almost the two thirds of renewable energy sources in the European Union are derived from biomass, including agri-food waste (Fischer and Schrattenholzer, 2001).

The use of agricultural residues and waste is already at a high level in several European countries (van Dam et al., 2007), but the use of energy crops has controversial aspects.

According to the EU Biomass Policy and Action Plan (EC, 2005) “biomass is essential for environmental and competitiveness reasons”. On the other hand the European Parliament adopted a note that “biomass has many advantages over conventional energy sources, as well as over some other renewable energy”. These advantages can be summarized, to the “low costs, less dependence on short-term weather changes, promotion of regional economic structures and provision of alternative sources of income for farmers”. For these reasons Rosillo-Calle argues that biomass production is high importance for rural areas and especially to the overall rural development (Rosillo-Calle, 2003).

According to Best (2003) “agro-energy refers to the energy function of agriculture, which can make significant contributions to achieving social and environmental sustainability at local, national, regional and global levels”. This goal can be achieved by using agricultural and livestock resources worldwide and many new technologies in order to transform the traditional uses of these resources to modern forms of energy (Best, 2003).

Based on the European axis of energy policy (EC, 2010) and the late development of renewable energy sources in Greece, the region of Macedonia is the best sample to examine the creation of agro-energy regions. It is assumed that the exploitation of agricultural and forest residues has only positive impact in terms of jobs creation and the generated thermal and electrical energy (Nishiguchi and Tabata, 2016). Also, the utilization of energy crops and the production of biofuels, has an overall positive impact worldwide (Bassegio et al., 2016). Greece depends heavily on imported forms of fossil fuels, and has high renewable energy production capacities and has set high goals. The objectives of Greece for producing any form of final energy from renewable sources reach 20% of total production by 2020 (REN21, 2016).

Multicriteria Methods for Biomass Production

In the literature applied many mathematical programming models in decision-making process of farmers. Examples are the multicriteria model for the assessment of rural development plans in Greece (Bournaris et al., 2014), the model for rural households to measure the effects of the Common Agricultural Policy (CAP) in three Southern European countries (Manos et al., 2013), and similar examples are the work of Valiakos and Siskos (2015) and Prisenk et al. (2014). The study will develop a ELECTRE III (ELimination and Et Choix Traduisant la REalite) mathematical programming model for ranking the agro-energy districts (regional units) of the region of Central Macedonia. Using a mathematical programming model is a top decision-making tool, as the ranking of agro-energetic districts in combination with the use of important criteria for farmers (eg maximizing profit, minimizing costs) creates a mixture of sustainable economic and environmental policy. Also, the multicriteria model of ELECTRE III has not been implemented anywhere in Greece for the analysis of biomass production through sustainable farms.

Many methodologies have been successfully applied for the biomass production in farm level such as Haas et al. (2000), Brentrup et al. (2001), Blengini και Busto (2009), Yu και Tao (2009) και Fedele et al. (2014). ELECTRE III multicriteria model will be used for the first time for ranking of agro-energy districts focusing on Central Macedonia and for biomass production. The great advantage of the methodology is that the results are presented clearly, facilitating the rational discussion of the results and the policy makers. The appropriate crop plans play a vital role in policy for biomass exploitation, especially in a sensitive environmental area since a large part of Macedonia consists of the Network areas Natura 2000. Therefore, this methodology is the most appropriate supportive tool for the ranking of the potentials of agro-energy districts and their combinations.

Methodology

The methodology section will present the main parts of the ELECTRE III multicriteria method and all the necessary mathematical equations.

ELECTRE III

The chosen model was ELECTRE III (ELimination and Et Choix Traduisant la REalite) multicriteria model. ELECTRE III is a well-known multicriteria method that chosen widely in the international literature. This method requires the determination of prices of three thresholds of the criteria which are used as the indifference threshold, preference threshold and the veto threshold (Banias et al., 2010). These allow the uncertainties of the evaluation criteria, be integrated into a decision-making process (Banias, 2009).

The ELECTRE III multicriteria model used widely in solving multi-criteria decision-making problems in order to determine the best alternative to a given problem using the multi-criteria analysis (Wang and Triantaphyllou, 2008). The only reason that this method could be meaningless is the lack of available weights of the criteria and/or the accurate and complete information in minimum preference limits (Banias, 2009).

Mathematical Model

We consider a number of g_j, criteria, where j=1,2,…r and a group of alternative scenarios A. Between the two scenarios a and b there is a possibility to have the following relationships and opposite (Banias et al., 2010):

- a**P**b: The a is strongly preferred to b, where $g(a)-g(b) > p$
- a**Q**b: The a is meager preferred to b, where $q<g(a)-g(b) \leq p$
- a**I**b: Indifference between a and b, when $|g(a)-g(b)| \leq q$

where p is the preference threshold and q the indifference threshold. The prices for p and q are set by the decision makers (Banias et al., 2010).

For the implementation of the ELECTRE III multicriteria model we introduce the relation with IPS = a**S**b symbolism, indicating that scenario a is at least as good as b. In order to examine the a**S**b statement introduces the following principles according to Buchaman et al. (1999):

- Agreement Principle: Applies a**S**b for the majority of the criteria.
- Principle of non-discrepancy: From all the criteria under which it accepted the statement contains no criterion on which this statement is strongly rejected.

The aSjb symbol indicates that scenario a is at least as good as b relative to the j criterion. In order the criterion j to be considered in accordance with the aSb statement should apply aSjb, ie $g_j(a) \geq g_j(b)\text{-}q_j$. Respectively the criterion j is in disagreement with the statement aSb when applicable $b\mathbf{P}_j a$, ie. gj(b) ≥ gj(a)-pj.

In general, the purpose of the method is defined as the ranking of alternative scenarios considering (Roy et al., 1986):

- The indifference and preference thresholds for each criterion.
- The criteria weights.
- the difficulties that may arise from comparing two scenarios, the first is significantly better than the second relative to a subset of criteria but inferior compared with the total evaluation.

Multicriteria evaluation of the potentials of biomass production of the regional units of region of Central Macedonia consists a problem which is formulated by using a set of alternatives (a, b, c, d, e, f, g) and a set of criteria (c1, c2, c3, c4, c5, c6, c7, c8). The evaluation of criterion j for alternative A is described as cj(A). The approach adopted in the framework of this analysis uses a ranking scheme following ELECTRE III principles, based on binary outranking relations in two major concepts; "Concordance" (cj) when alternative a outranks alternative b if a sufficient majority of criteria are in favour of alternative a and "Non-Discordance" (dj) when the concordance condition holds, none of the criteria in the minority should be opposed too strongly to the outranking of b by a. The assertion that a outranks b is characterized by a credibility index which permits knowing the true degree of this assertion (Roussat et al., 2009).

To compare a pair of alternatives (a, b) for each criterion, the assertion “a outranks b” is evaluated with the help of pseudo-criteria. As already discussed, the pseudo-criterion is built with two thresholds, namely indifference (qj) and preference (pj), for which the following apply (Banias et al., 2010):

- When cj(a)- cj(b) ≤ qj, the non-difference between alternatives a and b for the specific criterion j under study is identified. In this case cj (a, b) = 0.
- When cj(a)-   Vj(b) > pj, then a is strictly preferred to b for criterion j. In this case cj (a, b) = 1.

For a criterion j and a pair of alternatives (a, b), the concordance index is defined as follows (Banias et al., 2010):

$$c_j(a,b) = \begin{cases} 1 & g_j(b) - g_j(a) \leq q_j \\ 0 & g_j(b) - g_j(a) \geq p_j \\ \dfrac{p_j + g_j(a) - g_j(b)}{p_j - q_j} & q_j \leq g_j(b) - g_j(a) \leq p_j \end{cases}$$

A global concordance index $C_{a,b}$ for each pair of alternatives (a, b), is computed with the concordance index cj (A, B) of each criterion j (Banias et al., 2010):

$$c(a,b) = \frac{1}{\sum_{j=1}^{r} k_j} \sum_{j=1}^{r} k_j c_j(a,b)$$

where kj is the weight of criterion j.

As already mentioned, a discordance index dj (a, b) is also taken into consideration for all pairs of alternatives and each criterion j. Discordance index (dj) is evaluated with the help of pseudo-criteria with a veto threshold (vj), which represents the maximum difference cj(a) - cj(b) acceptable to not reject the assertion “a outranks b”, as follows (Banias et al., 2010):

$$d_j(a,b)=\begin{cases} 0 & g_j(b)-g_j(a)\le p_j \\ 1 & g_j(b)-g_j(a)\ge v_j \\ \dfrac{g_j(b)-g_j(a)-p_j}{v_j-p_j} & p_j\le g_j(b)-g_j(a)\le v_j \end{cases}$$

The index of credibility S(a,b) of the assertion “a outranks b” is defined as follows (Banias et al., 2010):

$$S(a,b)=\begin{cases} C(a,b) & \begin{array}{l} d_j(a,b)\le C(a,b) \\ \forall j \\ d_j(a,b)\ge C(a,b) \end{array} \\ C(a,b)\cdot \prod_{j\in J(a,b)} \dfrac{1-d_j(a,b)}{1-C(a,b)} & J(a,b): d_j(a,b)\rangle C(a,b) \end{cases}$$

In the case that a veto threshold is exceeded for at least one of the selected criteria, the index of credibility is null. In other words, the assertion “a outranks b” is rejected. As regards the ranking procedure of all available location alternatives Aj, two complete pre-orders are constructed through a descending and an ascending distillation procedure (Banias et al., 2010). In a nutshell, descending distillation refers to the ranking from the best available alternative to the worst, while ascending distillation refers to the ranking from the worst available alternative to the best (Roy and Bouyssou, 1993, Maystre et al., 1994). As a last step of the developed methodology, sensitivity analysis is available, since parameter values in real life applications originate from estimations which are sometimes more or less reliable (weighting factors, thresholds, criteria qualitative values etc.) (Banias et al., 2010).

The next step is to rank the scenarios according to the reliability table. Originally there are formed two rankings Z1 and Z2, one ascending and one descending preference respectively and from their combination we end up in the final standings Z = Z1 ∩ Z2 (Banias et al., 2010).

At this point it is inserted the constant λ, which is the highest reliability panel λ = max S(α,b) and is defined as s reliability value (λ), such as to remain only the values S(a,b) gene is greater than λ-s(λ).The reliability value, like boundaries pj, qj, vj above, determined by the decision-maker. Apply (Banias et al., 2010):

$$T(a,b)=\begin{cases}1 & S(a,b)\rangle\lambda-s(\lambda)\\ 0 & S(a,b)\langle\lambda-s(\lambda)\end{cases}$$

From the implementation of the last function derived the final scoreboard under which rankings will be achieved.

At the implementation of the ELECTRE III multicriteria model in this master thesis, it is used the "demo" version of the software developed by the French university «LAMSADE Paris-Dauphine» (LAMSADE, 2009)

Case Study Area

The Region of Central Macedonia (RCM) is divided into seven regional units, the regional unit of Chalkidiki, Imathia, Kilkis, Pella, Pieria, Serres and Thessaloniki. According to the biomass potential maps of the National Information System for Energy, the region of Central Macedonia has the largest reserves of biomass from agricultural residues throughout Greece.

In order to examine the potentials of biomass production in the Region of Central Macedonia (RCM), a ELECTRE III multicriteria model was chosen. All the appropriate technical and economic data of the total number of the agricultural holdings, collected from the General Directorate of Rural Economy and Veterinary and the Hellenic Statistical Authority.

Criteria

The selected criteria which used were eight, three economic criteria (gross margin, income and variable cost) and five environmental criteria (biomass production, production of thermal energy, production of electrical energy, thermal energy and electrical energy). A short description of these criteria is presented below.

Gross Margin

Gross margin is calculated using the data from prices, yields, subsidies and variable costs. This parameter was used as the best estimator of the farmers profit.

Income

Income is an important attribute of the system as it defines total agricultural output. It was computed by the simple combination of yields and prices, plus subsidies where applicable.

Variable Cost

In order to calculate variable cost all the agricultural inputs are summarized (seeds, fertilizers, chemicals, machinery, labour and the cost of water).

Biomass production

Based on the literature and taking into account newer research efforts in the same direction (Tziolas et al., 2016) the agricultural residues from larger crops per area and yield in tons per acre are calculated. The total amount of biomass produced for the crops residues of the agricultural holdings in the Region of Central Macedonia.

Table 1 Biomass production (tn/acre) from crops residues for the main crops of the Region of Central Macedonia

Crops	Residues type	Output of residues (tn/acres)	Humidity %	Biomass (tn/acre)
Alfalfa	Straw	0,30	0,15	0,26
Apples	Pruning	0,24	0,40	0,14
Apricots	Pruning	0,16	0,40	0,10
Barley	Straw	0,27	0,15	0,23
Cherries	Pruning	0,25	0,40	0,15
Cotton	Straw and shell (overground)	0,42	0,40	0,25
Cotton	Straw and shell (root)	0,13	0,56	0,06
Hard Wheat	Straw	0,16	0,15	0,14
Kiwi	Pruning	0,16	0,35	0,10
Maize	Stalks and cobs	1,05	0,55	0,47
Nectarines	Pruning	0,29	0,40	0,17
Olive Trees	Pruning	0,17	0,50	0,09
Peaches	Pruning	0,29	0,40	0,17
Rapeseed	Straw	0,40	0,53	0,19
Rice	Straw	0,38	0,25	0,29
Set Aside	Not applied	0,00	0,00	0,00

Soft Wheat	Straw	0,25	0,15	0,21
Sunflower	Stalks	0,40	0,40	0,24
Tobacco	Stalks	0,22	0,85	0,03

Production of thermal and electrical energy

In order to calculate the production of thermal and electrical energy for crops, the Lower Heating Values (LHV) were considered (Di Blasi et al., 1997, Menconi et al., 2013). In the final stage of calculating the production of thermal and electrical energy using the following formulas respectively:

Production of Thermal energy (MJ): 0:9 x Biomass (kg) x LHV(MJ/kg)

Production of Electrical energy (MJ): 0:2 x Biomass (kg) x LHV(MJ/kg)

Thermal and Electrical energy

The difference between the electrical and thermal energy depends on the performance of each boiler. The Lower Heating Values, LHV (MJ / kg), is higher in crops that their residues consist of branches, such as trees and lower in crops where their remains are straw.

Thermal energy (MWh): 0:9 x Biomass (kg) x LHV(MJ/kg) x Transformation coefficient Presuming that the boiler efficiency is 90 %.

Electrical energy (MWh): 0:2 x Biomass (kg) x LHV(MJ/kg) x Transformation coefficient Presuming that the boiler efficiency is 20 %.

Applying the above formulas, we calculate the electrical and thermal energy in MJ and then convert the output in MWh. The transformation coefficient is interpreted as a mode of designation for conversion the MJ values to MWh (1 MJ = 0.0002778 MWh).

Results and Discussion

In this section with the use of figures, graphs and tables, the main results will be presented. First of all, all the existent crop plans of the seven regional units of the region of Central Macedonia are discussed in detail. The following section shows the results as regards the potential biomass production, the electrical and thermal energy produced by crop residues and the results for the selected economic and environmental criteria. Finally, the main results will be the ranking of the seven regional units of the region of Central Macedonia after the implementation of the ELECTRE III multicriteria model.

Results

Crop Plans

As mentioned before, the crop plans of the seven regional units of the region of Central Macedonia are presented in the following tables. The data refers to the year of 2013 and they are collected from the Ministry of Rural Development and Food and the General Directorates of Rural Economy and Veterinary of each of the seven regional units.

According to the existent crop plans, it is observed that the region of Central Macedonia presents a great variety of crops (cereals, fruit trees, energy crops). At this master thesis, we focused only on the crops with the highest percent of cultivated area in each regional unit. Crops with percentages of cultivated area under 1% were not included in the analysis.

The analysis of the existent crop plans for the seven regional units of the region of Central Macedonia is presented with alphabetical order.

Olive trees has the highest percent of the cultivated area of the regional unit of Chalkidiki 41,50%, since Chalkidiki is well known in Greece for the olives and the virgin olive oil. The crops that follows are hard wheat with 21,82% and set aside areas with 16,04%. The cultivations with lower percent than 10% are barley with 5,74%, soft wheat with 4,92%, oats with 4,32%, vetch with 3,43% and sunflower with 2,23%. The total selected cultivated area of Chalkidiki regional unit is 743.292 acres.Level 2 Title

Table 2. Existent crop plan for the regional unit of Chalkidiki

Crops	CHALKIDIKI Area (acres)	%
Olive Trees	308.470	41,50%
Hard Wheat	162.180	21,82%
Set Aside	119.229	16,04%
Barley	42.658	5,74%
Soft Wheat	36.541	4,92%
Oats	32.142	4,32%
Vetch	25.491	3,43%
Sunflower	16.581	2,23%
Total	**308.470**	**100,00%**

Table 3. Existent crop plan for the regional unit of Imathia

Crops	Area (acres) IMATHIA	%
Peaches	182.357	28,05%
Cotton	163.544	25,16%
Maize	59.983	9,23%
Alfalfa	55.480	8,54%
Hard Wheat	48.420	7,45%
Nectarines	39.140	6,02%
Set Aside	27.784	4,27%
Apples	26.140	4,02%
Rice	16.240	2,50%
Soft Wheat	15.984	2,46%
Barley	14.935	2,30%
Total	**650.007**	**100,00%**

The regional unit of Imathia has 650.007 acres total selected cultivated area. The main crops of the regional units are fruit trees and arable crops. Analytically, the peaches hold 28,05% of the existent cultivated area followed by cotton with 25,16%. Under of the 10 percent of the cultivated area hold maize with 9,23%, alfalfa with 8,54%, hard wheat with 7,45%, nectarines with 6,02%, apples with 4,02%, rice 2,50%, soft wheat 2,30% and barley 2,30%. The existent crop plan of the regional unit of Imathia had set aside area 4,27%.

Table 4. Existent crop plan for the regional unit of Kilkis

Crops	Area (acres) KILKIS	%
Hard Wheat	382.478	42,16%
Soft Wheat	222.463	24,52%
Set Aside	99.099	10,92%
Cotton	68.141	7,51%
Alfalfa	44.087	4,86%
Barley	35.498	3,91%
Maize	33.949	3,74%
Sunflower	21.589	2,38%
Total	**382.478**	**100,00%**

The 42,16% of the cultivated area of the existent crop plan of the regional unit of Kilkis is covered by hard wheat. The soft wheat holds the 24,52% and 10,92% is set aside area. All the other crops which fill the existent crop plan of the regional unit of Kilkis presented percentage under 10%. Specifically, 7,51% is cotton, 4,86% is alfalfa, 3,91% is barley, 3,74% is maize and 2,38% sunflower.

Table 5. Existent crop plan for the regional unit of Pella

Crops	Area (acres) PELLA	%
Peaches	158.987	21,88%
Cotton	112.048	15,42%
Maize	84.987	11,70%
Cherries	78.251	10,77%
Hard Wheat	59.335	8,17%
Alfalfa	55.187	7,60%
Set Aside	49.983	6,88%
Soft Wheat	41.348	5,69%
Barley	40.640	5,59%
Nectarines	29.485	4,06%
Apricots	16.287	2,24%
Total	**726.538**	**100,00%**

As regards the regional unit of Pella, the highest percentage holds the peaches with 21,88%, followed by cotton (15,42%), maize (11,70%) and cherries (10,77%). Lower percentages had the hard wheat (8,17%), the alfalfa (7,60%), the set aside area (6,88%), the soft wheat (5,69%), the barley (5,59%), the nectarines (4,06%) and the apricots (2,24%).

The next crop plan is from the regional unit of Pieria. Pieria is well known for the cultivation of kiwis and tobacco but the main cultivations are the cereals. The highest percentage in Pieria regional unit holds the hard wheat with 20,53%, followed by soft wheat (15,70%) and tobacco (10,20%). Cotton with 9,30%, set aside with 8,70%, alfalfa with 7,00%, olive trees with 6,70%, kiwi with 6,50%, barley with 5,30%, maize with 3,70% and rice with 2,10% are the other main cultivations of Pieria.

Table 6. Existent crop plan for the regional unit of Pieria

Crops	Area (acres) PIERIA	%
Hard Wheat	94.987	20,53%
Soft Wheat	79.148	15,70%
Tobacco	48.888	10,20%
Cotton	46.148	9,30%
Set Aside	43.584	8,70%
Alfalfa	33.946	7,00%
Olive Trees	32.148	6,70%
Kiwi	32.184	6,50%
Barley	24.254	5,30%
Maize	17.545	3,70%
Rice	9.875	2,10%
Total	**462.707**	**100,00%**

The following table presents the existent crop plan for the regional unit of Serres. More analytically, it is observed that the regional unit of Serres has mainly arable crops and cereals. The cultivated area of hard wheat participate in the existent crop plan with 25,11%, the cultivated area of maize with 18,08% and the cultivated area of cotton with 11,10%. Soft wheat, sunflower and alfalfa participate with 8,93%, 8,05% and 7,62% respectively. The 6,18% of the cultivated area is set aside and barley holds the 5,86%. The cultivated area of olive trees, rice, tobacco and rapeseeds are follow with percentages lower than 5%.

Table 7. Existent crop plan for the regional unit of Serres

Crops	Area (acres) SERRES	%
Hard Wheat	335.270	25,11%
Maize	241.350	18,08%
Cotton	148.162	11,10%
Soft Wheat	119.245	8,93%
Sunflower	107.485	8,05%
Alfalfa	101.757	7,62%
Set Aside	82.458	6,18%
Barley	78.250	5,86%
Olive Trees	46.230	3,46%
Rice	31.045	2,33%
Tobacco	22.450	1,68%
Rapeseed	21.450	1,61%
Total	**1.335.152**	**100,00%**

Finally, the regional unit of Thessaloniki has 1.056.197 acres selected cultivated area. The 29,21% is covered by hard wheat, the 20,75% is covered by soft wheat and the 17,04% is covered by rice. At the existent crop plan of the regional unit of Thessaloniki participate also the following crops with percentage under than 10%, cotton (9,80%), set aside (8,04%), barley (5,04%), sunflower (5,00%), maize (2,84%), and olive trees (2,29%).

Table 8. Existent crop plan for the regional unit of Thessaloniki

Crops	Area (acres) THESSALONIKI	%
Hard Wheat	308.481	29,21%
Soft Wheat	219.112	20,75%
Rice	179.945	17,04%
Cotton	103.486	9,80%
Set Aside	84.945	8,04%
Barley	53.248	5,04%
Sunflower	52.845	5,00%
Maize	29.948	2,84%
Olive Trees	24.187	2,29%
Total	**1.056.197**	**100,00%**

Criteria

The second part of the analysis incudes the calculation of the eight indicators that will be used as criteria in the ELECTRE III multicriteria model. These indicators include three economic criteria (gross margin (€), farm income (€), variable costs (€)) and five criteria regarding biomass (biomass production, production of thermal energy (mj), production of electrical energy (mj), thermal energy (mwh) and electrical energy (mwh)). The calculations were made for the seven regional units of the region of Central Macedonia. The results are presented in the following table.

From the results we can conclude that the size of each regional unit is the most important factor for the results of the criteria. So, regional units with big size of agricultural areas present the highest values. The second important factor is the variety of crops in the existent crop plans. Regions with crops with high agricultural residues have better results as regards the biomass criteria. On the other hand, the number of crops that participate in the crop plan seems not to play any role for the criteria calculations.

Table 9 Calculation of the eight Criteria for ELECTRE III model

ALTERNATIVES	CRITERIA							
REGIONAL UNIT	GROSS MARGIN (€)	INCOME (€)	VARIABLE COST (€)	BIOMASS PRODUCTION	PRODUCTION OF THERMAL ENERGY (MJ)	PRODUCTION OF ELECTRICAL ENERGY (MJ)	THERMAL ENERGY (MWH)	ELECTRICAL ENERGY (MWH)
IMATHIA	82.639.292,18	210.811.094,64	128.171.802,46	153.941,88	2.565.940.026,60	570.208.894,80	712.818,14	158.404,03
THESSALONIKI	54.904.658,03	119.336.134,20	64.431.476,17	213.695,21	3.140.541.839,70	697.898.186,60	872.442,52	193.876,12
KILKIS	48.153.421,10	87.650.548,66	39.497.127,56	160.925,00	2.383.266.261,96	529.614.724,88	662.071,37	147.126,97
PELLA	174.610.011,65	317.328.408,48	142.718.396,83	161.579,45	2.686.299.186,15	596.955.374,70	746.253,91	165.834,20
PIERIA	50.209.550,87	104.365.027,78	54.155.476,91	77.115,67	1.175.256.301,05	261.168.066,90	326.486,20	72.552,49
SERRES	80.164.854,89	178.619.541,72	98.454.686,83	318.397,21	4.837.020.975,00	1.074.893.550,00	1.343.724,43	298.605,43
CHALKIDIKI	56.526.005,64	135.930.670,10	79.404.664,46	77.969,21	1.275.268.402,80	283.392.978,40	354.269,56	78.726,57

Ranking

The ranking of the regional units of the Region of Central Macedonia was performed using ELECTRE III multicriteria model. The eight criteria (gross margin, income and variable cost, biomass production, production of thermal energy, production of electrical energy, thermal energy and electrical energy) used to describe the characteristics of each regional unit of the Region of Central Macedonia as regards the economic and environmental aspects. Some of these criteria are conflicting which is important for the implementation of the ELECTRE III.

For the implementation of the ELECTRE III multicriteria model, it is necessary a set of weights for every criteria of our research. For this reason, a group of experts (included policy makers from the Ministry of Rural Development and Food, the General Directorate of Rural Economy and Veterinary, farmers and researchers) were interviewed. For the definition of the criteria's weights, a questionnaire was used through personal meetings. The results of the questions as regards the weights of each criterion are presented in the following table.

Table 10. Weights of each criterion

CRITERIA	WEIGHTS
GROSS MARGIN (€)	7.70
INCOME (€)	7.70
VARIABLE COST (€)	7.70
BIOMASS PRODUCTION	35.10
PRODUCTION OF THERMAL ENERGY (MJ)	11.10
PRODUCTION OF ELECTRICAL ENERGY (MJ)	9.80
THERMAL ENERGY (MWH)	11.10
ELECTRICAL ENERGY (MWH)	9.80

The implementation of the ELECTRE III multicriteria model in this master thesis was made through the use of the "demo" version of a software developed by the French university «LAMSADE Paris-Dauphine» (LAMSADE, 2009).

Each regional unit of the region of Central Macedonia took a unique alphanumeric code for software use. The alphanumeric codes were:

A0001: Regional Unit of Imathia

A0002: Regional Unit of Thessaloniki

A0003: Regional Unit of Kilkis

A0004: Regional Unit of Pella

A0005: Regional Unit of Pieria

A0006: Regional Unit of Serres

A0007: Regional Unit of Chalkidiki

The credibility matrix of the ELECTRE III multicriteria models for the regional units was:

Credibility Matrix

	A0001	A0002	A0003	A0004	A0005	A0006	A0007
A0001	1	0.15	0.92	0.85	0.92	0.15	0.92
A0002	0.85	1	0.92	0.85	0.95	0.077	0.98
A0003	0.81	0.15	1	0.67	0.98	0.077	0.9
A0004	0.92	0.22	0.92	1	0.92	0.15	0.92
A0005	0.077	0.21	0.15	0.077	1	0.077	0.92
A0006	0.92	0.92	0.92	0.85	0.92	1	0.92
A0007	0.077	0.15	0.15	0.077	0.92	0.077	1

Figure 1 Credibility Matrix

The concordance matrix of the ELECTRE III multicriteria models for the regional units was:

Concordance Matrix

	A0001	A0002	A0003	A0004	A0005	A0006	A0007
A0001	1	0.15	0.92	0.85	0.92	0.15	0.92
A0002	0.85	1	0.92	0.85	0.95	0.077	0.98
A0003	0.81	0.15	1	0.67	0.98	0.077	0.9
A0004	0.92	0.22	0.92	1	0.92	0.15	0.92
A0005	0.077	0.21	0.15	0.077	1	0.077	0.92
A0006	0.92	0.92	0.92	0.85	0.92	1	0.92
A0007	0.077	0.15	0.15	0.077	0.92	0.077	1

Figure 2 Concordance Matrix

After the implementation of the ELECTRE III multicriteria model, the following ranking emerged for the regional units of the Region of Central Macedonia where:

A0006>A0002> A0004> A0001> A0003 >A0005 and A0007

The final ranking of the alternatives (regional units) presented in the next figure:

Ranks in Final Preorder

Rank	Alternative
1	A0006
2	A0002
3	A0004
4	A0001
5	A0003
6	A0005 A0007

Figure 3 Final Ranking for the seven regional units.

Table 11. Final ranking of the regional units

Ranking	Code	Regional Unit
1	A0006	Serres
2	A0002	Thessaloniki
3	A0004	Pella
4	A0001	Imathia
5	A0003	Kilkis
6	A0005 and A0007	Pieria and Chalkidiki

From the table above, we can observe that as regards the potentials of the biomass production in the region of Central Macedonia, the regional unit of Serres has the first position, followed by the regional unit of Thessaloniki. The third position holds the regional unit of Pella, followed by the regional unit of Imathia. The fifth position holds the regional unit of Kilkis. The final position has the regional unit of Pieria and the regional unit of Chalkidiki.

From the results we can conclude that the size of the regional unit was an important factor. The crop plan of the regional unit of Serres seems to have the best crop mix between crops that produce biomass. The crop plan includes mainly arable crop and cereals as described in the previous section. The second crop plan, of Thessaloniki, seems to have similar crop mix with the regional unit of Serres. The following crop plans of Pella and Imathia are mainly covered by fruit trees.

The next figure shows, the ascending and descending distillations of the optimal regional unit which is Serres in our case, for the biomass production.

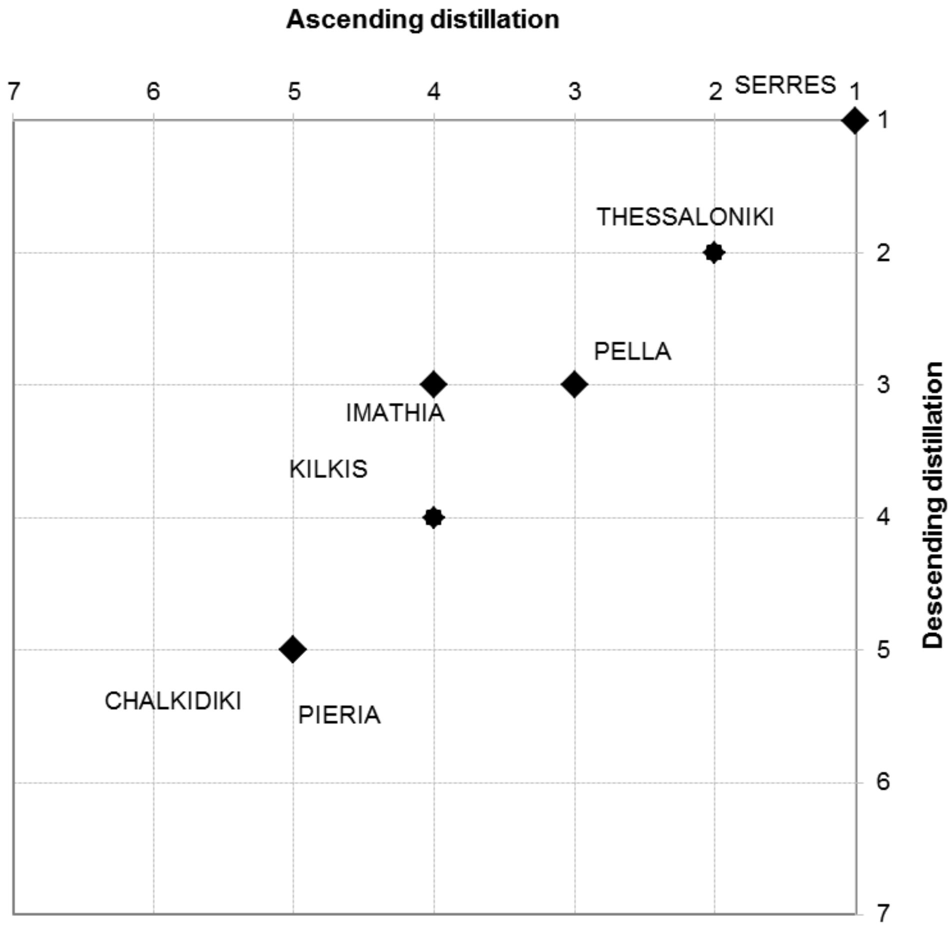

Figure 4 Ascending and descending distillations of the optimal regional unit for the biomass production

Conclusions

In this master thesis the potential of biomass production from agricultural residues in the region of Central Macedonia, was examined. For this reason, a research for the agricultural production of the seven regional units of the region was conducted and a number of agricultural indicators were calculated. The research also examined the thermal and electrical energy in MWh produced by the biomass from agricultural residues.

The results were presented in two parts. The first part examined the existent crop plans from the seven regional units of the region of Central Macedonia in Greece. The crop plans included the main cultivations in each regional unit and the potential production of biomass (tn/acre) of the cultivations. From the results we concluded that the crops that can produce biomass from their residues are mainly cereals and energy crops because they have plenty of straws and stalks which can produce high levels of biomass. From the crop plans we concluded that the main cultivations of Central Macedonia are cereals (hard and soft wheat), cotton and maize and in some regional units such as Pella and Imathia the main cultivations are fruit trees.

The main aim of the master thesis was to examine the optimal crop plan which can produce high levels of biomass. For this reason eight main indicators were calculated (gross margin (€), farm income (€), variable costs (€), biomass production (tn), production of thermal energy (mj), production of electrical energy (mj), thermal energy (mwh) and electrical energy (mwh)) for the seven regional units of the region. These indicators were used as criteria in a multicriteria analysis model. The multicriteria analysis model was developed under the ELECTRE III (ELimination and Et Choix Traduisant la REalite). This model was used to rank the crop plans of the seven regional units under the eight criteria that we have selected. The results showed that the regional unit of Serres had the optimal crop plan for biomass production in the region followed by the regional unit of Thessaloniki. These regional units had crop plans that included cereals (hard and soft wheat), maize, cotton and rice which are crops that produce high levels of biomass. The next crop plans were the crop plans from regional units of Pella and Imathia. These crop plans included fruit trees cultivations such as peaches and cherries which can produce high levels of residues from their pruning. From the above we can conclude that the biomass production in the region of Central Macedonia can be increased if the farmers turn to crop plans that include cultivation like those of the regional units of Serres and Thessaloniki. Also, in the multicriteria model ELECTRE III we used criteria such as gross margin and variable costs that are basic criteria for farmers decision making process, when they select the crops that will cultivate. On the other hand, as we know, their decisions are not include the biomass production. The multicriteria analysis managed to include these conflicting selection criteria in the model and the results of the ELECTRE III ranking proposed the optimal crop plans that the farmers can use and the policy makers can suggest.

The main policy messages from the master thesis is that the creation of agro-energy districts with the use of the proposed crop plan can lead to an increase of the farm income and to promote sustainable development for the rural areas using the agricultural residues for biomass production both for economic and environmental reasons. The proposed crop plans could be an important tool for the local and regional authorities, since it integrates the farmers will for profits and the social will for environmental issues. The ELECTRE III multicriteria model could be further improved in order to include more economic, environmental and social criteria that affect the biomass production. We intent in the future that the biomass production from agricultural residues will be one of the main criteria for farmers in their crop selection decision making process. We can suggest to the policy makers to encourage public and private investments in the production of energy from biomass and to encourage the creation of agro-energy districts in order to achieve better income for farmers and sustainable development for the rural areas.

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