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ENERGY ANALYSIS FOR APPLE GROWING IN PELION, CENTRAL GREECE

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Abstract

Our purpose was to conduct energy input analysis for apple growing in the 7 regions of mountain Pelion, central Greece, an excellent quality apple producing area. The energy inputs and fruit outputs were calculated for every operation and every coefficient of production for 3-6 apple growers per region and means and standard deviations and the relationships between energy inputs and outputs were calculated. Significant differences were found from region to region in Pelion due to mountainous terrain, the small farm size, the presence or not of specialized horticulturists and supporting hardware (meteorological stations, pheromone traps, etc) and software, and the local long experience in apple growing (which fosters higher than required chemical and manure inputs). In Pelion, pruning was an energy intensive operation for the areas with large size trees (over 50 years old), but plant protection with mean value of 24.1% and fertilization with mean value of 35.8% (including 18.5% for chemical fertilization and 17.3% for the manure applied) of the total inputs were the most energy intensive operations. From the coefficients of production, plant protection chemicals covered less than 5% of total energy inputs and reduction in their use seems difficult. On the opposite, due to mountainous terrain, the small size of the farms and the large tree size, significantly high inputs for machinery, fuels and supporting materials (21.4%, 16.2% and 17.7% of total, respectively) were found. As expected, the large quantities of chemical fertilizers and manure applied (16.8% and 17.3% of total, respectively) increased the total energy inputs. Finally, fruit production was relatively low, i.e. below 20 t ha^{-1}. Thus, we must focus mainly on the improvement of apple farm nutrition management and the conversion of low density large tree size farms to intensely-cultivated high density apple plantings to increase fruit production and reduce most of the energy inputs.

Keywords: *Malus x domestica*; energy balance; energy inputs; integrated production

1. INTRODUCTION

In mountain Pelion, central Greece, apple is cultivated for more than 150 years but widespread cultivation occurred after 1950 with the introduction of Red Delicious clones. Today apple production is around 30-40000 t from apple trees cultivated at 300 to 800 m elevation in a rough terrain with mainly large size and aged trees but with individual attempts to convert some of the farms to intensely cultivated with dwarf trees farms. In most of the regions, growers use their experience and the advice of horticulturist advisors based away from the farms, except in Zagora, where specialized horticulturists closely monitor problems and guide all farm operations based on integrated production protocols. Thus, rough terrain and small size farms (<1 ha), apple growing over the decades and mild climate causing a lot of endemic pest and disease problems, low irrigation water availability, and, generally, individually-guided cultivation and conversion of farms to more intensely cultivated are the major constraints of economic apple production in the region, except Zagora region, where the local cooperative has strictly applied integrated production protocols.

The IOBC and ISHS organizations describe integrated fruit production as the economic production of high quality fruit with environmentally safe methods, diminishing negative consequences and the use of pesticides to protect the environment and human health. Thus, the purpose of integrated production is to improve product quality without reductions in quantity, using proper available techniques to reduce inputs and environmental and human health impact [1].

If we need to assess their environmental and economic impact of all inputs, we must use a stable unit and not the economic analysis, as it does not take into consideration the environment and, due to inflation or when prices change, the results should be reevaluated. A safe long-lasting analysis method is based on energy units (MJ, kWh, kcal, etc) and this analysis could be easily converted to money at any moment and circumstance, using the cost of each input in each area and point in time.

Energy inputs in agriculture are divided in direct (fuels, machinery) and indirect (the cost of machinery construction, fertilizer production, etc) [2]. Nitrogen sequestration to fertilizers requires significant amounts of energy, thus its application significantly influences energy inputs. Also, pesticide production and machinery construction require significant indirect energy to produce. Human labour energy expression is highly debated, but we used a low energy equivalent, 2.2 MJ ha^{-1}, to pinpoint the importance of chemical and machinery inputs in our study [3].

Apple cultivation requires significant energy and capital inputs. Successful apple cultivation means reducing the economic cost without compromising the production and fruit quality, but also, whenever possible, increasing the fruit value (including improved quality and certification). Energy analysis can help distinguish the operations or coefficients of production that require and add significant amounts of energy to apple production, the analysts could modify these targeted inputs and

measure the final outcome as decreases in energy inputs, increases in marketable yield or, as a consequence, increases in energy use efficiency.
Energy analysis of apple cultivation has been conducted in a limited area of Zagora region a few years ago, when pilot application of integrated production protocols was studied [4]. The authors found that pest and disease management resulted in significant energy inputs (almost 40% of total inputs). Harvest operations and transport to storage facilities (21.6% of total) and fertilization (17% of total) were also intensive energy operations. Hand-thinning (including summer pruning), winter pruning and weed management also caused 8.1, 6.9 and 6% of energy inputs, respectively [4]. Finally, from the coefficients of production, fuels and machinery were the major input coefficients with 33 and 25% of total inputs, respectively, in the above study. Reganold et al. [5] compared organic, integrated and conventional apple production methods in U.S.A.. They found that conventional production had slightly higher fruit production outputs and higher energy inputs than integrated production even though integrated production significantly decreased fertilizer and weed management inputs. Thus, there is an interest in evaluating energy inputs and outputs in each region and for every cultivation method used.
The purpose of the certain study was to evaluate the energy balance for every apple producing region of Pelion, as it was expected that different practices are applied. This energy analysis would help us concentrate on the most energy-consuming operations or coefficients and try to propose measurable improvements to reduce chemical inputs and environmentally polluting outputs including CO_2.

2. MATERIAL AND METHODS

2.1 Present situation

Most farmers in Pelion mountain traditionally cultivate large trees >40 years old with >5 m height with 250-350 trees per ha. In the recent years, an unorganized conversion of traditional farms to more intensely cultivated schemes is taking place (with around 2000 trees per ha), whenever continuous irrigation water supply is available.
Pests causing significant problems in Pelion include codling moth (*Carpocapsa pomonella*) with 2-3 generations yearly and two aphids (*Aphis pomi*, *Dysaphis plantaginea*). Chemical insecticide applications (4-6 times yearly) are used to protect the fruit and leaves. Apple scab is the major disease in the area and 6-12 fungicide applications (Cu, Ziram, etc) per year with portable mechanical sprayers are necessary to reduce damage to fruit and leaves. Only in Zagora, meteorological stations, proper software together with pheromone traps and field observations are used from the horticulturists to closely monitor pest and disease and guide plant protection precisely but to the safe side (to almost nullify damage!).
The same portable sprayers are used to apply herbicides to manage weeds (1-2 times per year), but, most commonly, weed cutters are used to control weed growth and thus avoid soil erosion (2-3 times per year). Winter pruning is done by hand using many available tools mechanised or not and supporting material like ladders. Similar tools are used for hand thinning and summer pruning. Chemical fertilizers and, sometimes, manure (<100 kg per tree, coming from sheep and goats) are used to cover (usually to a much larger extend than required) plant needs. Irrigation is done by flooding and furrows using gravity. Newer dense plantations use drip irrigation usually pressurised by gravity. Harvest is done by hand using ladders, buckets and field crates. After an initial sorting in the farm, the crates are transported to the storage facility or sold to wholesalers.

2.2 Methodology

The study was conducted in the apple producing regions of western, southern and eastern Pelion mountain, namely Drakia (with an unofficial young farmers' cooperative), Agios Georgios, Milies, Vizitsa, Neohori (with few but big size apple farms), Makrirahi plus Anilio and Zagora (where integrated production protocols are strictly applied). The study was based on questionnaires completed with personal interviews of 22 farmers in total covering around 20-40% of the active apple producers in each region except Zagora, where the files of integrated production protocols of six farmers were used and completed with required details via interviews by phone.
In order to better understand the coefficients of production used, we describe the machinery used for the various practices included diesel-powered trucks and only two tractors used by the participating producers. Also, we included hand-held weed mowers, portable pesticide applicators, pruning supporting compressors, chain saws and portable soil cultivators, all powered by gasoline. Supporting materials include the ladders for harvesting and pruning, hand-held pruning scissors and saws, crates and buckets for harvesting, and wooden poles for holding the fruiting branches. We also clarify that manure came from small ruminants after composting, in some cases fruit production was calculated as 80 kg per big size tree, fruit remained in field crates for four days, we did not include in the outputs the winter prunings even though they are burned, and the input of energy by the sun was not included as it is provided freely.
Energy input analysis was performed per producer for each operation and every coefficient of production. The energy contents of each factor were used as described by Strapatsa et al. [4] and Pimentel [6]. In short, for each operation the energy inputs of materials, fuels, incorporated into the machinery, supporting materials and humans were calculated. For each coefficient of production all energy inputs for all operations were summed up. The energy equivalent for manure used was 3.5 MJ kg^{-1}, even though there is an additional cost for manure transportation to the farms, which can be

substantially different in each case and impossible to calculate for all questionnaires.

Energy outputs included only the fruit sold expressed in kg and MJ per ha. Finally, the energy productivity (kg fruit produced / MJ of inputs) and energy efficiency (energy output / energy input) were calculated.

Table 1. Energy inputs (MJ ha^{-1}) for each operation in apple farms at different regions of mountain Pelion. Means and standard deviations are shown from 3-6 farmers per region.

	Agios Georgios	**Anilio-Makrirahi**	**Vizitsa**	**Drakia**
Pruning	11182 ± 16250	1448 ± 158	13618 ± 19845	9831 ± 6243
Thinning	2720 ± 1679	1597 ± 203	2085 ± 1346	1250 ± 440
Irrigation	4222 ± 268	2342 ± 2681	1525 ± 1316	2000 ± 731
Fertilization	20763 ± 19543	8324 ± 11726	10263 ± 4410	37027 ± 24693
Weed Management	9347 ± 3839	16462 ± 4394	10120 ± 4921	6435 ± 180
Plant Protect.	20154 ± 4678	12044 ± 1021	13101 ± 5293	12541 ± 1040
Harvest	11869 ±7517	10028 ± 3286	8747 ± 3191	11624 ± 2109
Other minor operations	410 ± 320	0 ± 0	55 ± 110	556 ± 15
Manure	26040 ± 28855	7753 ± 10964	33746 ± 7949	5914 ± 11829
Total – manure	80667	52245	59514	81264
Total +manure	106707	59998	93260	87178

	Milies	**Neohori**	**Zagora**
Pruning	13277 ± 5411	4145 ± 4045	1593 ± 919
Thinning	1723 ± 418	2121 ± 1555	1608 ± 908
Irrigation	508 ± 95	1059 ± 552	371 ± 266
Fertilization	1467 ± 2201	12003 ± 10379	6397 ± 5359
Weed Management	6255 ± 806	6825 ± 1545	3401 ± 1266
Plant Protect.	10747 ± 5861	19294 ± 8301	15837 ± 7421
Harvest	3394 ± 1938	9095 ± 8646	2090 ± 501
Other minor operations	279 ± 177	45 ± 90	184 ± 296
Manure	15613 ± 13814	3938 ± 5026	1564 ± 2829
Total – manure	37650	54587	31481
Total +manure	53263	58525	33045

3. RESULTS AND DISCUSSION

We found significant differences from farmer to farmer (shown by the standard deviation) and from region to region as presented in Tables 1 and 2. This means that producers even in the same region cultivated the apple farms and added inputs significantly different from each other. This was not coupled by different fruit production as standard deviation for fruit production was low (Table 3).

The energy input analysis per operation showed that Agios Georgios region had the highest inputs, followed by Drakia region (Table 1). The lowest energy inputs were calculated in Zagora. In Agios Georgios, the producers added significant quantities of chemicals and used a lot of supporting materials, which together added significant energy inputs to the apple farms (Table 2), to produce a medium quantity of fruit (Table 3). This situation resulted from the small farm size and the big tree size, which, even though they need careful time-consuming practices and thus high energy inputs, produce medium amounts of commercial quality fruit. In particular, in Agios Georgios plant protection added significant amounts of energy not from chemical use but from the use of machinery and fuel due to the above mentioned conditions (Tables 1 and 2). Finally, energy inputs for harvest were high due to the use of many supporting materials, human labor and the rough terrain and long distance from the cooling facilities.

In Drakia, the energy inputs were also high. In that region, the farmers were young with bigger than average farms, where in some parts they still cultivated the big size trees and in some they had planted high density small size trees on dwarf rootstock, which were not in full production yet. Due to these reasons, fruit production was relatively good for the Drakia region, but not high with international standards (Table 3). In Drakia, plant protection added small amounts of energy to the ecosystem as only few chemicals were used (Tables 1 and 2). Supporting materials added significant amount of energy as they were often used to complete the operations, namely pruning, thinning and harvesting. Harvest was an energy-consuming operation as machinery, fuel, human and supporting material energy inputs were high. Unfortunately, the young producers in Drakia added significant amounts of nutrients almost entirely in chemical formulations and very rarely manure (Tables 1 and 2). It is clear that their decisions for apple cultivation were based on and were confined from local experience, the concern for their health and the environment, the partial application of integrated production guidelines, lack of scientific support from competent local horticulturists and meteorological stations and lack of a critical mass of soil and leaf analyses to accumulate knowledge.

In Zagora region, supporting local horticulturists but also the danger to lose productivity and fruit quality were reflected in the energy analysis. In Zagora, the necessary chemical inputs were decided based on data from meteorological stations, insect pheromone traps, regular leaf and soil analyses and the experience and work of the local horticulturists. Thus, even though most of the trees in the region were of big size, the chemical inputs for pesticides and nutrients were the lowest in the whole area of Pelion (Table 2). But the energy inputs for plant protection were high due to the substantial use of machinery and fuel to apply the pesticides in the rough terrain and small size farms (Tables 1 and 2). In Zagora, the irrigation water is scarce, so irrigation and weed management consumed small amounts of energy, as fewer weeds grew and herbicides were used to kill them to avoid competition for water with the trees.

In Neohori, the apple farms had relatively big size and the trees were younger than in the other regions. Thus, many operations were completed with low energy inputs but with the use of machinery and supporting materials (Tables 1 and 2). Fertilization was based on many chemical inputs applied periodically. Plant protection was the highest energy input due to substantial use of pesticides but mainly due to the use of machinery and fuel.

In Milies and Vizitsa, the producers were old and the trees were of big size. So the traditional method of applying large amounts of manure (6 out of 7 producers used manure regularly) was the major energy input together with the energetic cost of pruning using many supporting materials (Tables 1 and 2). In Milies, most of the farms had only few trees as the old trees were dying out and the space was not replanted resulting in low fruit production (Table 3). Thus, most of chemical and other inputs were low except of manure, which was applied in large quantities. In Vizitsa, the substantial amounts of manure together with relatively high amounts of chemical fertilizers were obvious for a medium fruit production for the Pelion area (Tables 2 and 3).

Finally, in the regions of Anilio and Makrirahi, energy analysis showed that most of the inputs were due to weed management, while fertilization and plant protection were done sparingly with relatively low inputs (Tables 1 and 2). The high energy cost of weed management was the result of the periodic weed cutting more often than in other regions as more irrigation water is available and applied and the microclimate of the region is humid with high rainfall (>1000 mm of rain and snow) with medium temperatures. This humid climate resulted in more often use of fungicides (and the subsequent related energy inputs) in this region and the neighboring Zagora (Table 2).

When we analyzed all regions together per operation, we found that pruning was an energy-consuming operation (mean overall value of 10.8%) due to the big size of the trees, but, for the same reason and the small size of the farms, plant protection and fertilization [with mean overall value of 24.1% and 35.8% (18.5% for fertilizers and 17.3% for manure), respectively] were the major energy consuming operations in Pelion. This result was concluded with the 15 of the 28 producers taking part in the study using manure regularly. Thus, fertilization should be our major target in the attempt to reduce energy inputs in the region. We should conduct nutrient balance studies by measuring the inputs and outputs of nutrients, as it is expected that nutrient use is substantially lower than nutrient inputs [4]. We should also propose to perform more soil and leaf analyses and organise and analyze them properly to develop better knowledge of possible deficiencies or imbalances of nutrients and the plant needs. These together would help us develop an integrated approach for proper use of nutrient inputs, reduce energy inputs and improve productivity and fruit quality.

When the coefficients of production were analysed for all regions together, all pesticides added less than 5% of total energy inputs, something that is possibly difficult to reduce further but a result that could be used as promotion to consumers for the fruit of the area. But, for the application of these pesticides and all other operations, large energy inputs were calculated for machinery use (21.4% of total), fuel (16.2% of total) and supporting means (17.7% of total). In addition, as mentioned before, large inputs were calculated for chemical fertilizers (16.8% of total) and manure (17.3% of total).

Table 2. Energy inputs (MJ ha^{-1}) for each coefficient of production in apple farms at different regions of mountain Pelion. Means and standard deviations are shown from 3-6 farmers per region.

	Agios Georgios	**Anilio-Makrirahi**	**Vizitsa**	**Drakia**
Insecticides	2950 ± 1670	1450 ± 750	1029 ± 846	807 ± 181
Fungicides	1707 ± 1123	2155 ± 1853	567 ± 352	369 ± 83
Herbicides	0 ± 0	357 ± 505	0 ± 0	111 ± 110
Machinery	16915 ± 5260	14803 ± 1862	13722 ± 1563	11267 ± 263
Fuel	15756 ± 6014	10653 ± 1717	10744 ± 2129	8776 ±1670
Fertilizers	20192 ± 19731	8278 ± 11707	10079 ± 4566	36965 ± 24671
Human labor	3679 ± 1330	3548 ± 745	2735 ± 1332	2492 ± 525
Supporting means	18419 ± 18254	8890 ± 2406	19781 ± 19430	18993 ± 7364
Irrigation water	1049 ± 755	2111 ± 2717	857 ± 1303	1484 ± 838
Manure	26040 ±	7753 ±	33746 ±	5914

	28855	10964	7949	± 11829

	Milies	Neohori	Zagora
Insecticides	446 ± 312	1276 ± 1074	1824 ± 997
Fungicides	296 ± 408	894 ± 1167	2307 ± 2665
Herbicides	0 ± 0	179 ± 357	540 ± 854
Machinery	10456 ± 3600	15058 ± 5791	11874 ± 5107
Fuel	7592 ± 1844	10912 ± 2625	8769 ± 3452
Fertilizers	1424 ± 2164	11361 ± 10807	3122 ± 4335
Human labor	2348 ± 291	3780 ± 2343	1954 ± 579
Supporting means	14967 ± 6413	10547 ± 11982	908 ± 230
Irrigation water	121 ± 73	580 ± 522	0 ± 0
Manure	15613 ± 13814	3938 ± 5026	1564 ± 2829

Fruit production varied from <8.5 up to 20 t per ha, quantity relatively low but common in the area of Pelion. Energy productivity for the different regions ranged from 0.15 to 0.46 kg MJ^{-1} (Table 3), values relatively low, but similar to the one found before for a certain area of Zagora (0.42 kg MJ^{-1}) [4] and in U.S.A. for conventional apple production (0.38 kg MJ^{-1}) [7]. Energy efficiency in Pelion was below 1 and even below 0.6 in some studied regions of Pelion. In accordance, energy efficiency was, in the previously mentioned studies [4, 7], 1.02 for Zagora (1 in our study herein for the same region) and 0.89 for U.S.A.

If we could organize a replanting plan of traditional farms with low planting density and big size trees to intensively cultivated farms with high density small size trees, wherever enough irrigation water is available, then fruit outputs would increase and inputs would decrease in most coefficients of production. Thus, energy productivity and efficiency would improve.

4. CONCLUSIONS

We found a large variability between the apple producing regions of mountain Pelion due to differences in climate, the rough terrain, small farm size, application of integrated production protocols, availability of local experienced horticulturists and hardware, the age of the producers, availability of economic resources for replanting apple farms and the availability of irrigation water. The economic analysis presented herein was able not only to help target the energy-consuming operations or inputs in general, but could be the tool to examine the results of any changes in the present practices.

5. REFERENCES

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Table 3. Energy outputs in kg and MJ per ha, total inputs per ha, energy productivity, energy intensity and energy efficiency from apple farms of each region of Pelion. Means and standard deviations (wherever appropriate) from 3-6 farms are shown.

	Agios Georgios	**Anilio-Makrirahi**	**Vizitsa**	**Drakia**
Outputs (kg ha^{-1})	16600 ± 10968	16894 ± 5035	13917 ± 4622	20197 ± 3543
Outputs (MJ ha^{-1})	36188 ± 23910	36829 ± 10977	30338 ± 10075	44029 ± 7723
Inputs (MJ ha^{-1})	106707	59998	93260	87178
Energy Productivity (kg MJ^{-1})	0.16	0.28	0.15	0.23
Energy Efficiency (inputs/outputs)	0.34	0.61	0.33	0.51

	Milies	**Neohori**	**Zagora**
Outputs (kg ha^{-1})	8395 ± 2653	13692 ± 16239	15101 ± 3397
Outputs (MJ ha^{-1})	18302 ± 5783	29848 ± 35400	32919 ± 7405
Inputs (MJ ha^{-1})	53263	58525	33045
Energy Productivity (kg MJ^{-1})	0.16	0.23	0.46
Energy Efficiency (inputs/outputs)	0.34	0.51	1.00