Topic 6
"Open topics"

Oral Presentation

Evaluation of Crop System Considering Both Economic and Energy Aspects with Web Application: The Use of Slurry Digestate as a Fertilizer Vs. the Traditional Mineral Fertilization

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Abstract

The experimentation was carried out during three years (2007-2009). The use of machinery and all other technical means was recorded and loaded into a web application made by the authors (www.biomass4energy.eu). The application compute the costs based on real machinery use and fit very well the needs of all kinds of farms and sizes. Both economic and energy balance for a single crop are presented. For the analysis the slurry was computed just the cost of the distribution and no-value (both energetic and economic) was given to the fertilizer. Were considered two farms of 30 ha each. The distribution of slurry was considered ad 1,5 km distance.

The results showed important economic convenience to use the digestate from biogas plants even if this fertilizer should be balanced with mineral fertilizers.

The most important result was the energetic balance: the crop treated with slurry yield Input/output ratio on average of 13,1, while the conventional crops reached 7,04. The net energy value was 175 GJ/ha vs. 140 GJ/ha for the slurry treated plots vs. the conventional treatment.

The web application allow a fair comparison of traditional and biomass crops and it is useful to assess not just the traditional crops but also the biomass crops, considering both economic and energetic aspects.

Keywords: economic balance, energy balance, crop comparison, slurry digestate

Introduction

The spreading of biogas plants in piedmont region lead to experimentation of the use of digestate from biogas plants on cereal crops that represent the majority of the land cultivated in the North-West of Italy.

Producing and selling energy with biogas plant is a brand new scenario for farmers, where often the lack of reliable and complete information are not enough to carry out a correct economic and energetic analysis.

There is still a need of a standardized application to verify the viability of a crop system or purchase of machinery at farm level. The use of the web present many advantages toward the standardization of coefficients and procedures, providing low cost service for the farmers (Berruto and Busato, 2006).

The aim of the research is contributing to knowledge which can be exploited in designing and evaluating biomass supply chains involves particular crop systems, within a standardized system approach. The application compute the costs based on real machinery use and fit very well the needs of all kinds of farms and sizes. Both economic and energy balance for a single crop are presented. This allow to compare the crops (e.g. cereals and biomass, corn and wheat, etc.) within the farm or groups of farmers.

The paper describes briefly the structure and the methodology used for the implementation of the WEB application and introduced a case study with two different cultivation scenarios, the use of slurry digestate as a fertilizer [BIOGAS] vs. the traditional mineral fertilization and adoption of rotation requested by PSR contribution scheme [PSR].

Methods

Implementation of the WEB application

The WEB application is made with the language Active Server Pages (ASP), connected to a database built with Microsoft® Access®. The multilingual (Italian and English) application could be accessed at: http://www.biomass4energy.eu.

The application consists of forms for data insertion and form for the presentation of the results. The access to the database is guaranteed in anonymous way (Berruto & Busato, 2006). The first phase concern the insertion of the following data: description of the farm; cultivated crops and their surface; tractors and equipments own by the farm; productive means prices (fertilizers, herbicides, pesticides, etc.).

During the second phase the user inserts the field operations. The logistic operations, such the transport of fertilizers and manure to the field, are considered separately from the traditional field work.

In the third phase the user could insert the sale of produce and other revenues, including the EU contribution and the cost for services paid by the farm (e.g. drying, grain harvesting, and irrigation expenses not related to agricultural equipment).

The database provide a list of machinery and tractors with all the coefficients needed for working time calculation which are the basics for the economic and energetic evaluation of machinery field work. Some of them were taken from agricultural mechanization books (Bodria et al., 2006; Hunt, 2001), while other come out of farm survey.

The application considered both direct (gas-oil) and indirect (chemicals, tractors and agricultural equipment) consumptions. The energy coefficients have been taken from different sources (Boehmel et al., 2008; Kitani et al., 1999; Nagy, 1999; Pimentel et al., 1999) and inserted in the database, so the user could compute the energy balance without the insertion of such coefficients.

Model Results

The results are showed both for single operation and for the crop.

The module with the results for the operation shows in detail: Working times for tractors and equipment (CIOSTA classification); Fuel consumption; Hourly cost for tractors and equipment; Unitary cost for the operation (€/ha); Unitary direct and indirect energy consumptions (MJ/ha).

For the crop, the application provides the following grouped results for both economic and energetic analysis: machinery cost; resource cost; extra-farm costs; total revenues; net income for the crop.

Case Study

Parameters and hypothesis for economic and energetic analysis

Two cropping systems were compared: BIOGAS and PSR, as described in the objective of the paper. For the two cropping systems compared was considered a farm area of 30 ha, with a four-year rotation crop. The technical-economic and energy calculations on a single crop are therefore reported to 7.5 ha. The field size was 2 ha (200x100 m) while the field distance was of 1,5 km.

We assume the operations were carried out with mechanical equipment owned by the farmer except for the harvest and drying of the product, carried out by contractors. The logistics operations were not considered in this analysis.

For both equipment and the inputs (herbicides, pesticides, fertilizers), were used as reference the prices of 2009. The prices of tractors and equipment were assumed as for a new purchase. The fuel has an average price of 0.62 € / kg in 2009.

The wheat straw was counted as sold on the ground, without baling operation, very expensive on small areas (7.5 ha). For the biogas slurry were calculated only the distribution costs and energy consumption for that operation.

For all crops was assumed the surface irrigation, with one intervention on sunflower, two on sorghum and three on corn (grain and silo). The cost of each operation was set at 80 €/ha (Berruto et al., 2009).

The times of use per year were calculated on the basis of the actual operations performed by a single machine or tractor.

The coefficients used in energy balance, converted into megajoules (MJ), were derived from the literature (1 tonne of oil equivalent = 41,868 MJ, according to International Energy Agency). The energy yield of sorghum and maize for silo was calculated using the energy contained in the methane produced before its conversion into electricity. The costs of labor and the rent of the land were not calculated and therefore form part of gross profits.

Results

The BIOGAS cropping system

<u>Technical and economic aspects</u>

At current market prices, biomass production allows higher incomes than cereals and oilseeds. This is particularly evident for sorghum characterized by increased production, lower cost of cultivation and higher MC than maize (26% DM versus 32% DM for corn silo), with no corresponding reduction in the price of the sale product . The gross margins were positive for all crops, because of less cost of fertilizers. Without PAC and PSR contribution, just the biomass crops present positive figures (Table 1).

<u>Energetic aspects</u>

All crops showed an output / input ratio exceeding 10. This is mainly due to lack of use of chemical fertilizers. The major energy inputs are associated with the consumption of diesel and corn herbicides. The balance of net energy per hectare of maize and sorghum biomass was respectively 4.88 and 5.28 toe/ha (Table 2).

Table 1. Economic balance for the BIOGAS cropping system.
All item are expressed in €/ha

Parameters	Wheat		Sorghum		Corn grain		Corn silo	
	Costs	Revenues	Costs	Revenues	Costs	Revenues	Costs	Revenues
Operation (equipment) cost	-415,42		-448,16		-508,12		-509,19	
Technical means	-150,62		-23,77		-454,85		-453,52	
Services	-359,73		-582,00		-608,93		-662,00	
Total	-925,77		-1053,93		-1571,90		-1624,71	
PAC contribution		292,53		292,53		292,53		292,53
PSR contribution								
Product sale		836,53		2452,48		1338,13		1800,40
Total revenues		1129,06		2745,01		1630,66		2092,93
Gross profit with contribution		203,29		1691,08		58,76		468,22
Gross profit without contribution		-89,24		1398,55		-233,77		175,69

Table 2. Energetic balance for the BIOGAS cropping system. All item are expressed in MJ/ ha

Parameters	Wheat		Sorghum		Corn grain		Corn silo	
	Input	Output	Input	Output	Input	Output	Input	Output
Fuel	-4.973		-5.767		-5.655		-5.871	
Tractors	-1.417		-1.402		-1.601		-1.583	
Equipments	-863		-906		-1210		-974	
Fertilizers	0		0		0		0	
Herbicides	-369		-590		-2.360		-2.360	
Pesticides, etc.	0		0		0		0	
Seed	-3.233		-94		-419		-419	
Technical input (total)	-3.619		-697		-2.798		-2.801	
Service input (total)	-1.634		-3.794		-3.326		-4.186	
Energetic input (total)	-12.506		-12.566		-14.590		-15.415	
Energy output (total)		139.886		233.752		163.561		219.649
Net Energy (MJ/ha)		**127.377**		**221.184**		**148.972**		**204.237**
Net Energy (toe/ha)		3,04		5,28		3,56		4,88
Output / Input ratio		**11,18**		**18,6**		**11,21**		**14,25**

The PSR cropping system

Technical and economic aspects

Because of low production and high costs, corn (grain production) presented a profit per hectare lower than other crops. Among the costs, the irrigation is very expensive with 3 interventions (240 € / ha). The cultivation of sunflower and maize, in the absence of PAC contributions, result in a loss. The profitability of the sunflower is a valid alternative to corn grain in areas with water shortages. The good production of rapeseed has enabled gains comparable with wheat. These two winter crops, showed good production with less cost and so presents the best results (Table 3).

Table 3. Economic balance for the PSR cropping system.
All item are expressed in €/ha

Parameters	Rape seed		Wheat		Sunflower		Corn grain	
	Costs	Revenues	Costs	Revenues	Costs	Revenues	Costs	Revenues
Operation (equipment) cost	-396,82		-429,89		-372,36		-509,58	
Technical means	-224,02		-334,04		-283,71		-673,60	
Services	-367,60		-359,73		-447,60		-837,87	
Total cost	-988,44		-1123,66		-1103,67		-2021,05	
PAC contribution		292,53		292,53		292,53		292,53
PSR contribution		120,00		120,00		120,00		120,00
Product sale		1097,60		1247,74		947,20		1707,33
Total revenues		1510,13		1660,27		1359,73		2119,86
Gross profit with contribution		521,69		536,61		256,06		98,81
Gross profit without contribution		109,16		124,08		-156,47		-313,72

Table 4. Energetic balance for the PSR cropping system.
All item are expressed in MJ/ ha

Parameters	Rape seed		Wheat		Sunflower		Corn grain	
	Input	Output	Input	Output	Input	Output	Input	Output
Fuel	-6.209		-6.883		-4.466		-5.490	
Tractors	-1.258		-1.375		-1.372		-1.790	
Equipments	-845		-873		-674		-1.136	
Fertilizers	-8.331		-10.297		-6.374		-14.336	
Herbicides	-590		-369		-1.475		-2.360	
Pesticides, funcicides	0		0		0		0	
Seed	-101		-3.233		-48		-419	
Technical input (total)	-9.022		-13.900		-7.896		-17.115	
Service input (total)	-1.763		-1.634		-2.155		-11.541	
Energetic input (total)	-19.097		-24.665		-16.563		-37.072	
Energy output (total)		124.578		204.949		125.425		208.689
Net Energy (MJ/ha)		**105.486**		**180.291**		**108.868**		**171.621**
Net Energy (toe/ha)		2,52		4,31		2,60		4,10
Output / Input ratio		**6,53**		**8,31**		**7,58**		**5,63**

Energetic aspects

For the PSR cropping system was clear the impact of fertilizers and herbicides on summer crops. In particular, maize has requested an energy twice as oilseeds and 50% higher against the wheat. The oilseed crops yielded net energy per hectare respectively of 2.52 and 2.65 toe/ha for rapeseed and sunflower, about half of that produced from corn and sorghum for biomass in the BIOGAS cropping system (Table 4).

Conclusion

Comparison of the two cropping systems

The net energy expresses the efficiency with which the crop use the soil resource. The BIOGAS cropping system allowed to produce 4.38 toe/ha and is therefore the most interesting at the moment, in the presence of water availability. In contrast, in the absence of biogas plant nearby the PSR cropping system is ensuring good average profit per hectare with a production of net energy of 3.38 toe/ha (Table 5).

Biomass production for BIOGAS plant

BIOGAS cropping system enables the best returns in economic and energetic terms, as at present the price of biomass is high, and so are the yields. This is the only system that has a cost of production per dollar of value produced less than 1. The convenience of using such a path is linked to water availability and proximity of plots to a biogas plant, which would reduce transport distances of biomass and waste products, thereby reducing time, cost and energy consumption related to logistics operations.

Where to plant oilseed crops

In the absence of nearby plants involved in the use of biomass is well suggest the use of the PSR – traditional cropping system. In the case it is difficult to practice irrigation, the farmer should carefully evaluate the convenience to produce oilseeds as summer crop. In particular, the sunflower is favored by using less water and thus lower the incidence of irrigation on operating costs and energy consumption.

Table 5. Overall comparative indexes of the two cropping systems

Parametri	BIOGAS	PSR
Gross margin (€/ha)	605	353
Ratio (PAC+PSR)/ha	293	413
Ratio Gross margin/(PAC+PSR)	2,07	0,86
Production cost ratio €/€Plv	0,81	1,13
Revenues PLV/ha (€/ha)	1607	1250
Net Energy value (MJ/ha)	175.443	141.567
Net Energy value (toe/ha)	4,19	3,38
Rapporto Output/Input	13,81	7,01

Importance of irrigation on production costs

The irrigation technique accounts for a major technical and economic aspects and energy. The implementation costs of irrigation are different depending on the systems used, although in many cases the water is not paid. They vary from 100 to 200 €/ha for surface methods to 520 €/ha with sprinkler. The irrigation with pivot costs about 250 €/ha, slightly more than some surface methods. It is obvious that choosing one or another cropping system should take into account also these aspects. More detail on irrigation costs and influence on energy balance could be seen in a specific publication on this issue (Berruto et al., 2009).

Logistic considerations

The economic and energy balances must also consider the impact of logistics operations, which is specific to each farm and is a function of the field distance from the farm. In particular, crops with high biomass production per unit, such as the silo of sorghum and maize, have high energy and transport costs when the distance is increasing. Results of testing performed by DEIAFA (Source: Project "Optimization of logistics sites of collection and transportation of biomass and waste for the biogas plants - Piedmont Region), indicate that the cost of the operation varies from 22 €/ha at a distance of 1 km to 181 €/ha about 10 km, up to 386 €/ha for 20 km. Depending on the distance of plots from the plant the gross profit may be, therefore, subject to large variations. The same issue apply for the distribution of slurry to be used for cultivation. The convenience to their use, compared with the use of mineral fertilizers, is limited to a radius of 10 km.

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References

Berruto, R. & Busato, P. (2006). EnergyFarm: Web Application to Compare Crop Systems Under Technical, Economic and Energetic Aspects. In *4th World Congress on Computers in Agriculture and Natural Resources*, ed. J. X. F. S. Zazueta, S. Ninomiya, G. Schiefer, Vol. I, American Society of Agricultural and Biological Engineers. Orlando, Florida USA, pp. 481-487.

Berruto, R., Busato, P. & Piccarolo, P. (2009). Economic and Energetic Analysis of Crop Systems Management Techniques by Means of WEB Application. In *XXXIII CIOSTA-CIGR V Technology and management to ensure sustainable agriculture, agro-systems, forestry and safety*, ed. G. G. G. Zimbalatti, Vol. I. Reggio Calabria, Italy, pp. 1093-1097.

Bodria, L., Pellizzi, G. & Piccarolo, P. (2006). *Meccanica agraria, volume II: la meccanizzazione*. Edagricole, Bologna.

Boehmel, C., Lewandowski, I. & Claupein, W. (2008). Comparing annual and perennial energy cropping systems with different management intensities. *Agricultural Systems*, **96**(1/3), 224-236.

Hunt, D. (2001). Farm power and machinery management, Vol. I, IOWA University Press, pp. 77-93.

Kitani, O., Jungbluth, T., Peart, R. M. & Ramdani, A. (1999). Energetic analysis coefficients. In *CIGR Handbook of Agricultural Engineers*

Vol. V, pp. 13-39.

Nagy, C. (1999). Energy coefficient for agriculture inputs in Western Canada. *CAEEDAC report*.

Pimentel, D., Pimentel, M. & Karpenstein, M. (1999). Energy use in agriculture: an overview. In *CIGR E-journal,* Vol. 1, pp. pdf file.

Energetic and Ergonomic Aspects in the Photovoltaic Greenhouses

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Abstract

Crops in greenhouses in Italy are made using prefabricated structures, leaving out the preliminary study of optical and thermal exchanges between the external environment and the greenhouse, speaking with heating and cooling for the effects of air conditioning needed for plant growth. This involves operating costs rather significant that directed the interest of designers, builders farmers and to seek constructive solutions to optimize the system such emissions.

Were analyzed aspects of the structural components and their thermal and optical properties to achieve a representation of reality, as well as the microclimatic parameters. In order to estimate the risk for workers, the air temperature, radiative temperature, and air speed were measured using instruments in conformity with ISO 7726.

A model was constructed considering an example of a prefabricated greenhouse located in central Italy and devoted to the nursery: the model provides to simulate electricity production, internal lightness and microclimatic parameters. The data show how the risk of a hot microclimate for the workers (defined with the PHS index) must not be underestimated.

Keywords: renewable energy, heat exchange, microclimate

Introduction

Aim of this study is to test the response of the software TRNSYS simulation of climate parameters in a greenhouse. We want to create a template:

- detailed design of structures,
- to optimize resources,
- to verify the use of new energy systems to agricultural activities.

To simulate the greenhouse have been proposed several studies to obtain values forecasts or simulations of influential variables for protected crops, such as ventilation (Fernandez and Bailey, 1992), the water temperature for hydroponic systems (Zhua, and Deltourb Wang, 1997), the control of CO_2 for Carbon fertilization (Linker, Seginer and Gutman, 1998), the moisture budget (Jolliet, 1994), climate control (Occhipinti and Nunnari, 1996) and heat exchange (Beccali, Giaccone and Panno, 1992). Recently, the thermal behavior of the greenhouses was studied using dynamic thermal simulation tool TRNSYS 15.1. (Pavlou, Sfakianaki, 2007).

Due to the actual strain of researching optimal solutions for the use of resources, is important to create a model that includes all variable influential on greenhouse microclimate. Values of climatic parameters representative of reality are obtained taking an existent photovoltaic greenhouse as reference and creating a simulation project with TRNSYS 16 software.

Another aim of the research is to assess the risk for workers due to microclimate conditions.

Materials and methods

Photovoltaic greenhouse

The photovoltaic greenhouse in this study is located in Rome. It was designed and built through cooperation between Artigianfer and Isofotòn. It has been tested and connected to the grid by engineers Isofoton in May 2009. It consists of a 246.16 kWp photovoltaic system that receives a fee of 0.43 €/kWh for the full architectural integration instead of glass on flap south.

The system consists of 1456 high efficiency modules Isofoton IS-170/24 transparent laminates, unframed, allowing full integration in place of windows. The distance between cells, studied in the design stage, allows the passage of light making possible the operation of nursery underlying coverage. Under the cover are positioned 36 inverter SMA Sunny Mini Central 7000 TL, placed on metal structures to improve the visual impact.

Greenhouse structural description

The greenhouse considered is an Artigianfer type STO construction with steel structure prefabricated, used as a greenhouse for growing flowers and plants. It is covered with glass cover horizontal beam pattern and small flaps with north-south orientation.

Has a width of 25.60 m divided into two spans of 12.80 m. It is 150.107 m long and is divided into 39 sections ranging from 4.035 m. the eaves height is 4.60 m. In terms of structural elements, the greenhouse has cross doors.

Symmetric and transverse frames are stuck at the bottom and top. They are made with tubular columns 120x80x3 mm Fe 360 and horizontal beams lattice currents 80x40x3 mm Fe 430 tubular rods and rod wall. The roof rafters are made from the water canal collector and of pressed sheet metal. The side purlins are made of C-sections from 90x50x1.8 mm made of cool folded sheet. The glazing consists of rods 12 and 14 mm for roofs and walls. The calculation was performed in accordance with the requirements of the UNI-EN 13031-1 for greenhouses with metal structure. The maximum unit stress for steel Fe 360 of 1,600 kg/cm^2 for the first load cases and 1,800 kg/cm^2 for the other; for steel Fe 430 are of 1,900 kg/cm^2 for the first load cases and 2,135 kg/cm^2 for the other. These have a corrosion protection due to the galvanizing bath.

The greenhouse consists of 8 very narrow aisles, each of 3.2 m, characterized by two sloping roof pitches of 22° degrees (40%) and exposed north-south. On south-facing slopes are placed photovoltaic modules, glass is used wholly within the aquifer north. The PV panels near the front side were not fitted for plates of tempered glass for a very specific reason: the force of the wind may be pushing on the end of the greenhouse and could blow up the last panels. For the high cost of a PV module, it seemed appropriate don't install in these areas to avoid the risk of rupture of the modules.

Table 1. Structural specifications

Span width	12.80 m
Span length	150.107 m
Aisle width	3.20 m
Eaves height	4.60 m
Step columns	4.035 m
Ventilation Doors	2.00 m
Between pitch	40% (22°)
Doors	width m 2.50, height m 3.00

The greenhouse is equipped with continuous full-stop in the north stratum (the glass) driven by motors with rack system if the temperature inside the greenhouse exceed a given temperature. This automated system therefore depends on measurement of a temperature sensor located near the slopes. Outside the building is also home to a wind instrument in the case of strong wind forces the system to automatically reclose.

Photovoltaic modules

The PV modules produced by Isofoton, are made with pseudoquadrate monocrystalline silicon cells high efficiency for energy conversion of solar radiation into DC electricity.

The cell circuit is laminated using EVA (Ethylenevinylacetate) as encapsulating a complex of tempered glass on the front and a plastic polymer (TEDLAR) on the back, resistant to environmental agents and provided with electrical insulation.

The variation of electrical modules, depending on the temperature is as follows:

the voltage decreases at a rate of 2.22 mV / ºC for each cell in series containing the module and for every degree above 25 ºC;

- the current increases at a rate of 17 $\mu A/cm^2 \bullet$ ºC area of the cells in parallel and for every degree above 25 °C.

It must be said that the cabinet temperature referred, does not coincide with the temperature, since the cell is heated as a result of sunlight incident. The increase in temperature of the cell, in relation to air temperature, is the characteristics of that building and that of the module.

Depending on the incident radiation, temperature and position of power, a photovoltaic module can operate with different values of voltage and current.

Table 2. Design features

Cell type	Monocrystalline, textured, anti-reflective layer
Dimensions	125 mm x 125 mm
Number of cells per module	72 cells in series
Structure	1) Tempered glass and microstructured high transmissibility
	2) Cells laminated with EVA (ethyl-vinyl acetate)
	3) Back to back Tedlar / Polyester layers

Table 3. Reference values for system integration

Maximum allowable tension in the system	1,000 V
Reverse current	2 h overloaded to 135% of the maximum security
Upload physical maximum allowable	5,400 Pa
Operating temperature	-40 ºC a 85 ºC
Impact resistance	Hail of 25 mm, 1 m to 23 m/s
Dimensions	1,597 x 800 x 45 mm
Weight	14.6 kg

Table 4. Electrical behaviour at standard conditions and at 800 W/m^2, NOCT, AM 1, 5°

Parameters	Standard	800 W/m^2
Maximum Power	170 W	121.6 W
Open circuit voltage	44.8 V	40.8 V
Voltage at the point of maximum power	36.2 V	32.4 V
Parameters	Standard	800 W/m^2
Short circuit current	5.20 A	4.10 A
Current in maximum power point	4.28 A	3.8 A
Module Efficiency	13.8 %	
Tolerance	± 3 %	± 3 %

Inverter

The efficiency of a PV power plant is directly related to that of his drive. The inverter controls the installation and is therefore a central element in ensuring the energy efficiency.

During the planning commissioners, asked that the 36 inverters installed in the building. This is a fairly high number for this type of PV power plant, for which he usually choose fewer but higher power. This is justified by the fear that the failure or rupture of an inverter lose large amounts of energy, while it would be compromised in this way only one thirty-sixth. The inverter used is the Sunny Mini Central SMC 7000 TL brand SMA (Table 5).

Table 5. Inverter specifications

Input	
Max DC Power	7200 W
Max DC Voltage	700 V
PV-voltage range, MPPT	333 V – 500 V
Input current max	22 A
Number of maximum power point tracker in	1
Maximum number of strings (parallel)	4
Output (AC)	
Rated power AC	7000 W
Max AC Power	7000 W
Output current max	31 A
Rated voltage / range	220 V – 240 V / 180 V – 260 V
Frequency AC (self) / Interval	50 Hz /± 4,5 Hz
Power factor (cos φ)	1
AC connection / power compensation	phase
General Data	
Max Efficiency	98.0 %
EURO-ETA	97.7 %
Dimensions (width x height x depth) in mm	468 /613 / 242
Weight	32 kg
Operational temperature range	–25 °C ... +60°C
Consumption: operating (standby) / night	<10 W / 0,25 W
Typology	transformerless
Cooling technology	OptiCool

Greenhouse modelling

The implementation of the model was carried out by using the program TRNSYS. The model creation was done through the Simulation Studio, starting with the path led to the construction of a "multizone building", which is divided into multiple steps where the user enters the data on the building and its location. After creating a preliminary draft is possible editing the greenhouse description the that those inside the, opening TRNBuild directly from the icon building (Type56) add other components in the project, as the central PV and the inverter.

The greenhouse was modelled using the parameters already described in previous paragraphs, to simulate the heat exchange panels were made of materials not found in libraries provided by the program.

For a correct simulation of humidity inside the greenhouse must consider the input of water due to transpiration of plants. Since the calculation of the transpiration of plants is extremely complex models should be entrusted to a specific Type to run but is not one of those available in the program. To simplify the introduction of these constants of water transpired during the year found in the bibliography. The constancy of these values depends on the type of nursery practice and length of the cycle of the plants.

Upon completion of all changes, the graphical display of the project in Simulation Studio appears in the figure below (Figure 1).

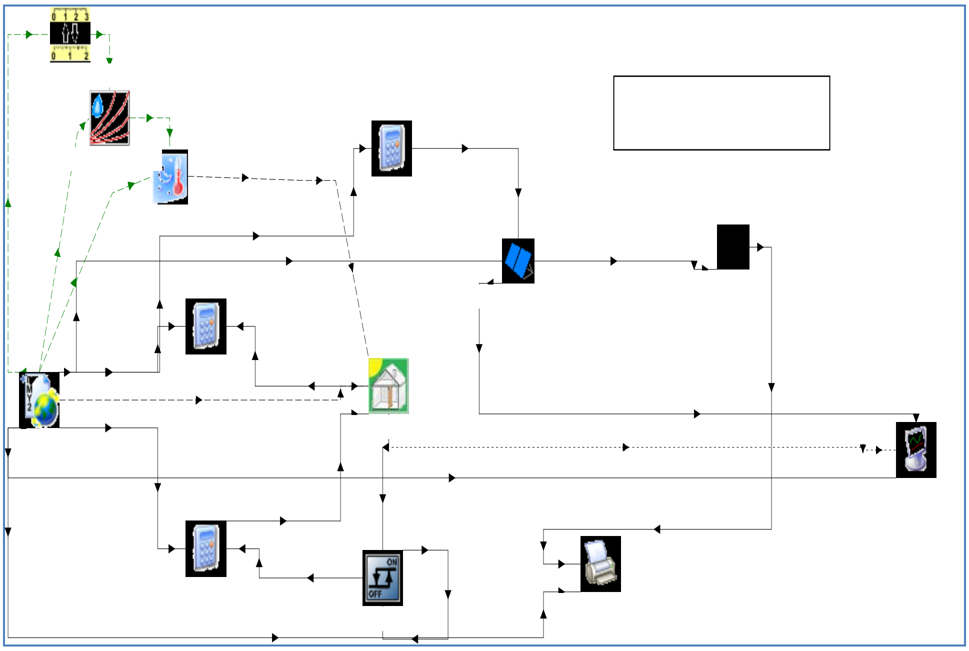

Figure 1. Graphic display of the project in Simulation Studio, where icons represent: Rome: weather data reader; Psychrometrics: psychrometric processor; Sky Temp: CPU sky temperature; Unit change: unit converter; Greenhouse: Greenhouse (Type 56); Nat. Vent.: controllers of natural ventilation; Natural Ventil.: airchanges from natural ventilation; Infiltrations.: airchanges from infiltration; Photovoltaic: photovoltaic array model; Inverter: inverter model; System Printer: data generator; Online Plotter: charts generator.

The PHS method for risk assessment

In order to evaluate the risks for workers operating inside the greenhouse, data such as the air temperature, the average radiative temperature, and the speed of the air were used. These parameters, together with subjective parameters (worker clothing and physical activity) were used to calculate the predicted heat strain (PHS) for the workers in compliance with ISO 7933 (ISO, 2004). European regulation EN ISO 7933 (ISO, 2004) replaces the previous regulation (EN 12515). The new regulation contains a criterion of evaluation of workers' exposure to hot environments that, even though based on references similar to those included in the previous regulation, presents numerous new and different elements. The method has some limitations, in particular the fact that it can only be applied within a defined range of environmental and subjective parameters. Moreover, heart rate is not included in the physiological parameters.

As with all indices that integrate elements of the thermal environment, interpretation of the observed levels of PHS requires careful evaluation of the workers' activity, their clothing, and many other factors, all of which can introduce large errors into any predictions of adverse effects (Budd, 2008).

The PHS method serves to limit duration of work based on two types of risk: (1) core body temperature, and (2) dehydration, due to required sweat loss (Malchaire et al., 2001).

Results

The project carried out with TRNSYS, it allows to extract all variables time-dependent, running simulations for hourly time periods established by the user, from a single hour to one year.

Microclimatic simulations

There were initially simulated climatic parameters inside the greenhouse, with particular reference to the variables that affect plant growth: temperature, humidity, wind speed, solar radiation inside the greenhouse. Were chosen day of the year when temperatures reach the limit values, January 12 for winter and July 20 for the summer. The variables were related to the printer and extrapolated data were processed on Excel and shown in the table below.

Table 6. Microclimatic parameters inside the greenhouse on days considered as resulting from simulations.

hour	air temperature (°C)		relative humidity (%)		air velocity (m/s)		internal radiation (W/m^2)	
	12-gen	20-lug	12-gen	20-lug	12-gen	20-lug	12-gen	20-lug
1	13.53	20.81	59.41	64.45	0.03	0.06	0.00	0.00
2	10.17	21.11	52.26	80.17	0.04	0.06	0.00	0.00
3	11.12	20.69	41.31	87.73	0.05	0.06	0.00	0.00
4	9.80	20.58	41.95	90.14	0.09	0.06	0.00	0.00
5	9.81	20.32	40.72	92.12	0.10	0.04	0.00	0.00
6	9.09	20.52	42.32	91.69	0.11	0.02	0.00	44.20
7	8.80	21.64	43.12	87.92	0.14	0.02	0.00	121.60
8	8.32	23.33	44.72	82.94	0.15	0.02	0.00	221.20
9	8.61	25.17	44.67	78.60	0.13	0.03	44.30	306.30
10	9.41	27.14	44.50	73.13	0.13	0.05	88.20	361.20
11	10.16	28.97	44.94	67.57	0.14	0.07	144.20	421.20
12	10.87	30.66	45.23	62.47	0.12	0.08	170.90	447.80
13	11.62	32.06	45.32	58.35	0.09	0.08	188.90	452.40
14	12.22	33.13	45.60	55.22	0.09	0.07	191.50	441.90
15	12.48	33.80	46.33	53.03	0.08	0.06	146.70	397.80
16	12.30	34.00	47.62	51.92	0.07	0.05	113.80	331.30
17	11.85	33.81	48.84	52.10	0.07	0.06	50.70	254.20
18	11.04	33.44	50.88	52.98	0.08	0.04	0.00	194.70
19	10.49	32.43	52.21	55.71	0.13	0.03	0.00	42.10
20	10.24	31.14	52.57	59.20	0.16	0.02	0.00	5.30
21	9.87	30.37	53.47	61.09	0.12	0.02	0.00	0.00
22	9.57	29.70	54.17	62.52	0.10	0.02	0.00	0.00
23	9.21	29.04	55.01	63.46	0.13	0.02	0.00	0.00
24	9.93	25.77	59.00	62.10	0.12	0.04	0.00	0.00

Temperature simulations

To get a graphical view of temperatures, it is been created a daily simulation comparing inside temperature, outside temperature, photovoltaic panel surface temperature, mean radiative temperature on the inner surface of the walls, operative temperature.

The charts in Figure 2 shows the simulation results on the January 12 and July 20.

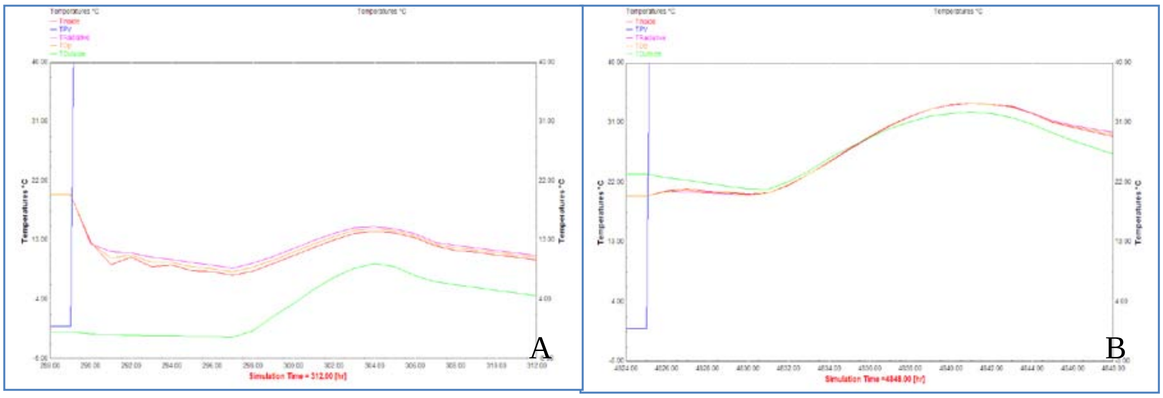

Figure 2. Left. Simulation of temperature on January 12 (A) and July 20 (B) where: Tinside: inside temperature; TPV: temperature of the photovoltaic panel surface; TRadiative: mean radiative temperature on the inner surface of the walls; Top: operative temperature; TOutside: outside temperature

Energy production

The following chart shows the annual simulation of electric power [W/m^2] generated by a m^2 of panels, represented in blue. In red is shown the annual simulation of total solar radiation incident on the panels [W/m^2] with the scale of values on the left axis.

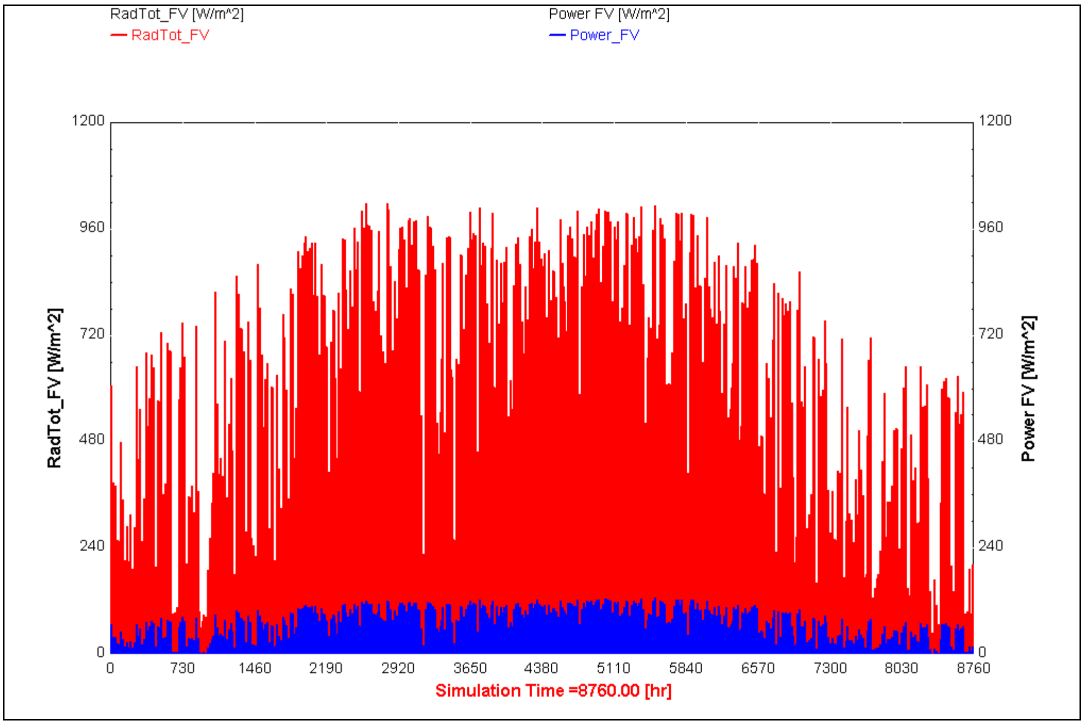

Figure 3. Simulation of the annual electrical power generated and the incident radiation, where: RadTot_FV: total radiation incident on one m2 of photovoltaic panels; Power_FV: electric power generated by a m2 of photovoltaic panels.

It was then simulated the annual electricity production of the entire plant, which is about 250 MWh output of the inverter.

Risk assessment

The following output values are obtained by applying the PHS model using as input data the values of microclimatic parameters estimated for the date of July 20, obtained as described above and relating to the eight hours between 7.00 am and 3:00 am, and considering a 'moderate' business for the worker (while standing, with continuous use of the arms) (Met = 150 W/m2) and a clothing consists of shorts, shirt, suit, socks and shoes (Clothing insulation : Icl = 0.8 clo):

- maximum allowable exposure time for heat storage (Dlim tre): 131 min;
- maximum allowable exposure time for water loss, mean subject (Dlimloss50): 480 min;
- maximum allowable exposure time for water loss, 95% of the working population (Dlimloss95): 480 min.

In case of lack of water availability, values Dlimloss50 and Dlimloss95 could lowered to 288 minutes.

Conclusions

TRNSYS software has proven its extreme flexibility to allow development of the project emissions. The construction of the model has been simplified by the procedures explained in a comprehensive manner in the various manuals provided with the software, without showing any particular difficulties in communications between the constituent subprograms.

As for the light component of the simulations, the solution found to allow the passage of long wave radiation through the glass of the greenhouse modelled as "windows", has perhaps shown a critical factor on TRNBuild, not have the optical model for light energy to the walls of buildings, but this did not affect in any way the results. Moreover, this solution has improved the simulation of moisture for the cold bridge effect.

From this model, it might be interesting to continue to work on projects for energy systems applied to agriculture, being able to predict the indoor climatic conditions and from this starting to figure out which crops are actually achievable.

In addition, this program offers many opportunities to improve systems made: will be inserted cooling and heating, dehumidification, the total consumption of electricity and machinery for the exercise of individual farming, the heat emitted by workers, plants and the various electrical components inside the greenhouse and everything else necessary to simulate the reality situations inside a greenhouse. Could be easily build a new components (Type) on variables purely "agricultural" as soil evaporation and plant transpiration of water.

The data concerning work in the greenhouse, analyzed with the PHS model, show a potential health risk for the workers, especially concerning their heat storage. However, we must consider that the data should be confirmed with "in field" measurements. Furthermore, we must remember to put plenty of drinking water at the workers' disposal. In fact, the maximum values of water loss can be easily exceeded.

References

Beccali G., Giaccone A., Panno G. 1992, Modello di calcolo per l'analisi del comportamento termico delle serre. Energie alternative HTE, 4(18), luglio-agosto, 283-289 4(19), settembre-ottobre, 405-415.

Budd G. M., 2008, Wet-bulb globe temperature (WBGT): Its history and its limitations. J. Sci. Med. Sport 11(1): 20-32.

Fernandez J.E., Bailey B.J., 1992, Measurement and prediction of greenhouse ventilation rates, Agricultural and Forest Meteorology, 58, 229-245.

Hollands, K.G.T., D'Andrea, L.T., Morrison, I.D., 1989, Effect of random fluctuations in ambient air temperature on solar system performance, Solar Energy, Vol. 42, 335-338.

ISO, 2004, ISO 7933: Ergonomics of the thermal environment: Analytical determination and interpretation of heat stress using calculation of the predicted heat strain. Geneva, Switzerland: International Organization for Standardization.

Jolliet O., 1994, HORTITRANS, A Model for predicting and optimizing humidity and transpiration in greenhouse. Journal of Agriculture. Engineering Research, 57, 23-37.

Linker R., Seginer I., Gutman P.O., 1998, Optimal CO2 control in a greenhouse modeled with neural networks. Computer and Electronics in Agriculture, 19, 289-310.

Malchaire, J., Piette A., Kampmann B., Mehnert P., Gebhardt H., Havenith G., den Hartog E., Holmer I., Parsons K., Alfano G., Griefahn B., 2001, Development and validation of the predicted heat strain model. Ann. Occup. Hyg. 45(2): 123-135.

Occhipinti L., Nunnari G., 1996, Synthesis of a greenhouse climate controller using AI-based techniques. Proceedings of the 8th Mediterrenean Electrotechnical Conf., Vol. 1, 230-233, Bari, May 1996.

Pavlou K., Sfakianaki a., 2007, Improvement of the energy performance of greenhouses, 28th AIVC Conference on Building Low Energy Cooling and Advanced Ventilation Technologies in the 21st Century, Crete island, September 2007.

Perez, R., Stewart, R., Seals, R., Guertin, T., 1988, The development and verification of the Perez diffuse radiation model, Sandia Report, Albuquerque, October 1988.

Reindl D. T., Beckman W. A., Duffie J. A., 1990, Diffuse fraction correlations, Solar Energy, Vol. 45, No. 1, pp. 1-7.

Reindl D. T., Beckman W. A., Duffie J. A., 1990, Evaluation of hourly tilted surface radiation models, Solar Energy, Vol. 45, No. 1, pp. 9-17.

Stephenson, D.G., Mitalas, G.P., 1971, Calculation of heat conduction transfer functions for multi-layer slabs, ASHRAE Annual Meeting, Washington D.C., 22-25 August 1971.

Zhua S., Deltour J., Wang S. 1998, Modeling the thermal characteristics of greenhouse pond systems, Aquacultural Engineering 18, 201–217.

Effects of the Quality of the Biomass on Combustion Emissions of Stoves and Small Boilers

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Abstract

Particulate matter is one of the most important indicators of air quality and has also a significant impact on human health. The negative contribution of small biomass stoves on air quality is so evident that some Italian regional administrations had to adopt urgent regulations. In this work, the relationship between emission quality and biomass characteristics related to the combustion of biomasses with different properties was assessed in a 13 kW pellet stove and a 150 kW wood chip boiler. Test combustion using biomass with high moisture and ash content produced higher particulate concentrations. The values relevant to the pellet stove ranged from 110 to 360 mg/MJ utilizing different types of biofuel. Also the biomass stove fed with low quality wood chip increased the dust emissions. These data highlight the current limitations of biomass burning in small plants and should encourage manufactures to improve the technology level of their heating devices. Anyway, considering the possibility to supply biomasses from agriculture and agro-industry, the development of technical standards appears one of the most interesting ways of approaching these problems, allowing a comparison between biomass producers, manufacturers devices and monitoring bodies.

Keywords: air quality, particulate matter, biomass quality

Introduction

The increase of fuels prices has encouraged the development of alternative energy sources especially at household and rural level. However, biofuels are generally more difficult to burn respect the standard fossil fuels, due to incorrect and/or inconstant combustion occurring in stoves and small boilers. As a consequence, the exhausts could contain significant amount of hazardous substances, like particulate matter (PM) and partially oxidized organic compounds (Nikolaou, 1984; Swartz, 1995; Mccrillis, 1992).
Physical dimension and size distribution of fine parts of the biofuel and the technical features of stoves and boilers are the most important parameters that influence the quantity and the characteristics of the pollutants. PM could originate from inadequate mixing between combustion air and biofuel, from high biomass' ash content, low combustion temperatures and short residence times of the combustion gases at higher temperatures. These are some of the most important conditions causing the increase of PM concentration in the exhausts (Van Loo, 2008).
According to a world global estimate, 50% of households use biofuels for heating and cooking (WHO, 1992). In Italy about 20% of households burns wood more than 4 times a year in more than 5 million domestic wood stoves (APAT, 2008) and the wood consumption in small devices is estimated in 3-6 millions of t/year. In some Italian regions the PM from biomass combustion is considered a serious problem and the Authorities are introducing some drastic restrictions like the ban of biofuels in some locations.

Considering these problems and also the need to increase the production of renewable heat, it is urgent to find new solutions for the control of the quality of the biofuel and of the emissions of stoves and small boilers. The most critical parameter is the PM and in this work, developed by the Biomass Laboratory of the Polytechnic University of Marche, are given the results of some combustion tests carried out with a stove, a boiler and different grades of solid biofuels.

Materials and methods

Combustion tests were conducted in two different heating systems: a 13 kWt pellet stove and a 150 kWt woodchip boiler. Each heating system has been fed with different types of biomass. In the case of the stove were used two types of pellets with different ash content. In the case of the boiler, combustion tests were carried out with two types of wood chips (A and B) and blends of wood chips with grape residues.

Table 1 shows more in detail the combustion test planning and relative information.

Table 1. Type of heating systems, biomass and power used during tests.

DEVICES	BIOMASS	OPERATING CONDITIONS
Domestic stove	Pellet A	P2 and P4
Domestic stove	Pellet B	P2 and P4
Boiler	Wood chip A	90 kWt
Boiler	Wood chip B	90 kWt
Boiler	Wood chip + Grape residues	90 kWt

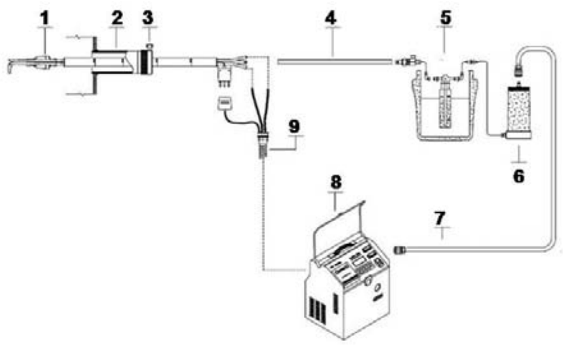
In the case of the stove, samples were collected at two different loads: 5.4 (P2) and 9.4 kWt (P4). In the case of boiler a setting of 90-105 kWt was chosen.

Analytical laboratory methods specifically developed for solid biomass were applied on each biofuel. In particular, it was considered to the purpose of this study to measure the moisture content, the ash content and the calorific value according to the technical standards defined by CEN/TC 335 on solid biomass (table 2).

Table 2. Technical normative used for biomass characterization.

TECHNICAL NORMATIVE	DESCRIPTION
CEN/TS 14774:2004	Solid biofuels - Methods for the determination of moisture content - Oven dry method
CEN/TS 14775:2004	Solid biofuels - Method for the determination of ash content
CEN/TS 14778-1:2005	Solid biofuels - Sampling - Part 1: Methods for sampling
CEN/TS 14780:2005	Solid biofuels - Methods for sample preparation
CEN/TS 14918:2005	Solid Biofuels - Method for the determination of calorific value

For the determination of the PM was adopted the method described in the standard UNI EN 13284-1. The gas sampling system was based on an isokinetic probe (MiniStack Tecora) that has an internal filter to capture the PM from warm exhausts using an AISI 316 probe.



1. *Filter box (25 mm di diametro)*
2. *Sampling point*
3. *Sliding and fixture elements*
4. *Silicon tube*
5. *Cooler*
6. *Silica gel trapped*
7. *Isokinetic tube connector*
8. *Isokinteic sampling systems*
9. *Termocouple tube*

Figure 1. Apparatus for the determination of particulate matter.

Figure 2. Ministack probe on boiler chimney (left) and pellet stove (right).

The dust emissions values were calculated comparing the mass of dust filtered with the volume sampled. Data were normalized according the above mentioned standard and expressed also in relation to the energy produced.

Results

Table 2 summarizes the results of the biofuels characterization. It is possible to observe the strong difference in terms of ash content between the two types of pellets used in the domestic stove. More in particular, the first type is considered within the quality class "A" according to UNI TS 11263, while the pellet B would fall into class "C". There are also strong differences between the characteristics of the biomass used in the tests on the boiler. Besides the difference in terms of ash content, there are strong differences in terms of moisture content.

Table 2. Characteristics of the biomasses used during the test combustions.

		Pellet A	Pellet B	Wood chip A	Wood chip B	Blend
Moisture content	($\%_{ar}$)	8.2	8.3	25.5	47.2	38
Ash content	($\%_{dm}$)	0.5	2.4	1.7	2.9	4.1
Net calorific value	(MJ/kg_{ar})	16.9	16.2	13.4	12	10.7

Note: ar = as received; dm = dry matter.

The results of combustion emission test in the case of pellet stove, are shown in table 3 and figure 4. It is interesting to observe that the values are related to the ash content of biofuel and also to load of the stove. Higher is the pellet quality, lower are the values of PM (mg/Nm3).

Table 3. Results of test combustion in pellet stove.

Pellet	Ash content (%)	Operative conditions	PM (mg/Nm^3)	PM (mg/MJ)
A	0.5	P2	93.4	141.5
A	0.5	P4	142.0	108.4
B	2.4	P2	97.5	169.3
B	2.4	P4	243.0	356.4

Figure 3. Particulate filter before (left) and after (right) test combustion.

Figure 3 shows the filter before and after the test. In this case, the black color of the filter indicates the carbonaceous organic nature of the particulate.

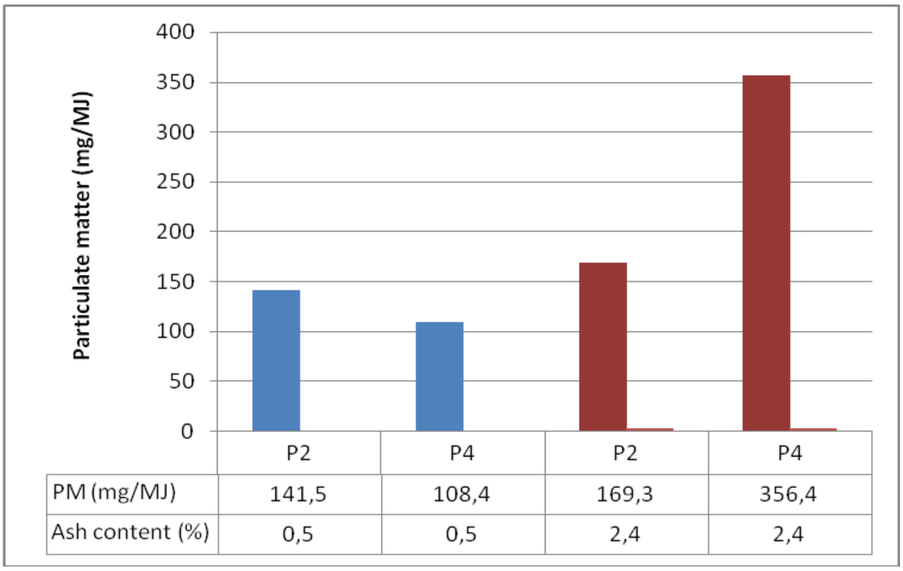


Figure 4. PM level for different biomasses and combustion conditions in the pellet stove.

The quality of biomass has a significant influence even in the case of combustion in the boiler. Test results with different types of biofuels are shown in figure 5, which highlights differences in PM (mg/Nm3) that are very high even using the same type of biomass (wood chip), but with different characteristics (type A and B). In this case the moisture content is the most important parameter. The quality of the emissions significantly reduced in the case of blend that, besides higher moisture content, presents also an higher ash content of the wood chips.

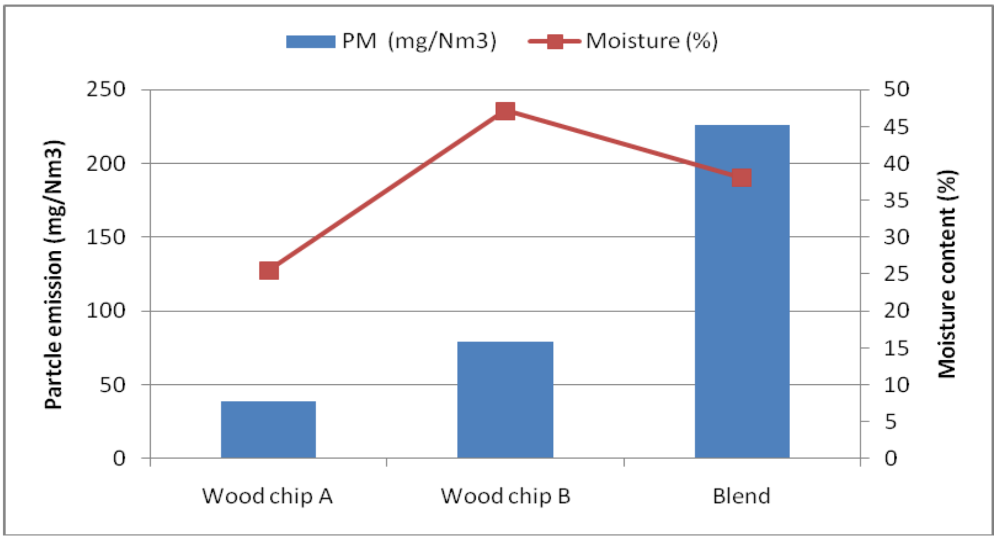


Figure 5. PM level for different biomasses in the heating boiler.

Conclusions

Small heating devices based on the combustion of solid biomass may originate wide variations in terms of quality of gaseous emissions. Indeed, the biofuels with high values of moisture and ash content increase the mass of pollutants.

In the case of wood pellets, that are considered as the best biofuel in the field of the solid biomasses, the variation of PM can range from just over 90 mg/Nm^3 to 240 mg/Nm^3 depending on the ash content. The difference between the best and worst measure increases if the values are referred to the energy produced. In this case, the values range from about 110 to 360 mg/MJ.

Similarly, referring to the boiler test, the combustion quality is affected by the moisture content of biomass. Increasing the moisture content from 25 to 45% the value of PM is doubled. The addition of a problematic fuel like grape residues (30% in mass) leads to over 200 mg/Nm^3 of particulate (above the Italian law limit).

In conclusion, the control of the PM emissions require some actions:

- it is necessary to request the user to use quality biofuels especially in terms of ash content in the case of pellets and at least adequate moisture content for wood chips;
- verify that the compliance with the biomass manufacturer's specifications ensure a good quality level of emissions.

Taking into account that poor quality biomasses from agriculture and agro-industry are more abundant, the development of appropriate technical standards appears one of the most interesting ways to approach these problems allowing a comparison between biomass producers, manufacturers devices and monitoring bodies.

References

Nikolaou K, Masclet, P., Mouvier G. Sources and chemical reactivity of polynuclear aromatic hydrocarbons in the atmosphere — A critical review. Sci Total Environ 1984;32:103.

Swartz RC, Schults, D. W., Ozretich, R. J., Lamberson, J. O., Cole, F. A., Dewitt, T. H., Redmond, M. S., Ferraro, S. ΣPAH: a model to predict the toxicity of polynuclear aromatic hydrocarbon mixtures in field-collected sediments. EnvironToxicol Chem 1995;14:1977.

Mccrillis RC, Watts, R. R., Warren, S. H. J. Effects of Operating Variables on PAH Emissions and Mutagenicity of Emissions from Woodstoves. Air Wastes 1992;42:691.

WHO. Indoor Air Pollution from Biomass Fuel. Report of a WHO consultation. Geneva, Switzerland; 1992.

APAT 2008. Stima dei consumi di legna da ardere per riscaldamento ed uso domestico in Italia.

UNI/TS 11263:2007. Biocombustibili solidi - Caratterizzazione del pellet a fini energetici.

UNI EN 13284-1:2003. Stationary source emissions. Determination of low range mass concentration of dust. Manual gravimetric method.

Van Loo S., Koppejan J.. 2008. The handbook of biomass combustion adn co-firing, Earthscan.

Preliminary Results of a Field Study on Goats Milk Yield and Lactation Persistency as Affected by Automatic Cluster Removals

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Abstract
Automatic cluster removers (ACRs), although rarely adopted in goats milking, are available to remove milking equipment after milking. Main advantages of ACRs are overmilking reduction, improved teat condition, labour saving, improved milking routine. An innovative flow-based ACR for sheep and goats was coupled with an electronic milk meter was installed on the 16+16 parallel milking parlour with 32 milking units of the experimental goat farm associated with the University of Milan.
Two balanced groups of 12 Saanen goats each were selected according to parity and days in milking. Animals were milked twice a day., and the milking machine was set up to provide 90 pulsations/min in a 50:50 ratio with a vacuum level of 42 kPa. One group was milked with an ACR switch point of 70 g/min and a delay time of 10 s, while the reference one was milked disabling the ACRs. Reattachment of milking units to goats was discouraged. Individual milk yields were recorded at each milking session through electronic milk meters and the flock management software.
Milk yields recorded on the whole lactation were analyzed to evaluate the ACR effect on goats daily milk production, and by nonlinear regression, to determine Wood's lactation curves of the two groups. Results highlighted a higher mean milk daily production for the ACR group with 1.82 kg vs 1.68 kg of noACR group ($P < 0.001$). The results showed that ACR group reached significantly higher milk production with a significant better persistency during the whole lactation.

Keywords: ACR, dairy goats, peak of lactation, milking persistency

Introduction

Automatic cluster removers (ACRs) are available to remove milking equipment after milking in most of the new milking parlours for dairy cows. ACRs detach the milking units when the milk flow drops below a preset level (kg/min) and an additional delay time can usually be set to determine how long (s) the milking unit must remain attached to the udder after the flow level is reached. Main advantages of ACRs are overmilking reduction, improved teat condition, labour saving, improved milking routine, while disadvantages include cost, maintenance and reliability (Rasmussen, 1993).
Many studies were carried out to examine effects of ACRs settings on machine on-time, milk yield, and udder health in dairy cows. Traditionally cows have been regarded correctly milked when the milk flow rate drops below 200 g/min. A reduction in machine-on time without having a negative influence on milk yield was observed by Rasmussen (1993) with the 0.4 kg/min vs. 0.2 kg/min setting and by Stewart et al. (2002) who compared ACR settings of 0.5, 0.64, 0.73, and 0.82 kg/min. Magliaro and Kensiger (2005) reported a similar milk production for the 0.48 and 0.6 kg/min settings, but a reduction by 0.5 kg/milking for

the 0.8 kg/min setting. In their study an ACR setting of 0.6 kg/min resulted in faster milking times without sacrificing milk production.

Reduced machine-on time may also decrease the incidence or severity of teat-end lesions and potentially reduce the occurrence of mastitis providing health and economic benefits for the farmer (Neijenhuis *et al.*, 2000, 2001).

In dairy goats machine milking the adoption of ACRs is quite new and there are few reports on the effect of ACRs on milking performances in the scientific literature (Tangorra *et al.*, 2007, 2008).

Aim of the study was to evaluate the ACRs effects on milk yield and lactation persistency in goat lactation.

Materials and methods

An innovative flow-based ACR for sheep and goats developed by Guidobono Cavalchini *et al.* (2004) was coupled with an electronic milk meter (AfiFree™ S.A.E. AFIKIM). The system was installed on the 16+16 parallel milking parlour with 32 milking units of the "Gian Paolo Guidobono Cavalchini" experimental goat farm associated with the University of Milan, Italy. In detail, the system implemented (Figure 1) was constituted by:

- a telescopic bar, hinged just below the floor of each milking stall, with a special support to which is connected the milking unit. The bar allows to keep the milking unit steadily near the udder, working as a vertical stabilizer of the same milking unit. In this way a good coupling between the teats and the milking unit is ever guaranteed over the entire milking, avoiding that teats are folded and strained during the progressive udder emptying;
- an actuator of the bar, consisting of a small pneumatic piston, which allows to remove the milking unit from the udder at the end of milking;
- a high resolution free-flow milk meter to measure the milk yield and flow rates, enabling the detaching of the milking unit when the milk flow drops below a preset level.

From an available flock of Saanen goats, two balanced groups of 12 animals each were selected according to parity (1-3) and days in milking (10 ± 5). The two groups were housed separately in the same stall with external paddocks and received the same total mixed ration (TMR) as fed. The ration contained alfalfa hay, mixed hay, triticale silage, dried pulp, and concentrate (16.33% crude protein, 3.78% crude fat, 35.14% NSC, non-structural carbohydrates, and 38.66% NDF). Animals were milked twice a day at 5 a.m. and 5 p.m., and the milking machine was set up to provide 90 pulsations/min in a 50:50 ratio with a vacuum level of 42 kPa. Between February and October 2007, one group (ACR group) was milked with an ACR switch point of 70 g/min and a delay time of 10 s, while the other one (noACR group) was milked disabling the ACRs. Reattachment of milking units to goats was discouraged. Individual milk yields were recorded at each a.m. and p.m. milking session through electronic milk meters (AfiFree™ S.A.E. AFIKIM) and the flock management software (Afigoats™ S.A.E. AFIKIM).

Figure 1. The innovative flow-based ACR installed on the milking parlour of the experimental farm of the University of Milan

The ANOVA of the individual milk traits was performed using the GLM procedure of SAS (SAS, 2008). The model contained the effects of treatment (presence or absence of automatic cluster removal), days in milking, number of lactation, and their interactions, random effect of goats nested within treatment, and residual error. Significance was declared at $P \leq 0.05$ and values are presented as least square means with pooled standard errors.
Milk yields recorded on 210 d of lactation were analyzed by nonlinear regression P-NLIN (Marquardt method) procedure of SAS (SAS, 2001) to determine lactation curves of each individual goat. Parameters were calculated utilizing the Wood's equation (Wood, 1967):

$$Y(n) = a n^{b} e^{(-cn)}$$

where:
Y = milk production;
n = time interval;
a = a scaling factor to represent yield at the beginning of lactation;
b = slope of the ascending phase to the peak (index of the animal's capacity to use energy for production);
c = slope of the descending phase to the peak (decay rate).

The DIM at peak yield (Y_{max}) was defined as b/c, and Y_{max} was calculated as $a(b/c)^{b}e^{-b}$. The coefficient of determination was used as an index to assess the goodness of fit.

Results

Results highlighted a higher mean milk daily production for the ACR group with 1.82 kg of milk vs. 1.68 kg for the noACR group ($P < 0.001$), revealing a positive effect of ACR on milk yield. The lactation curves of ACR and noACR groups are shown in Figure 2.

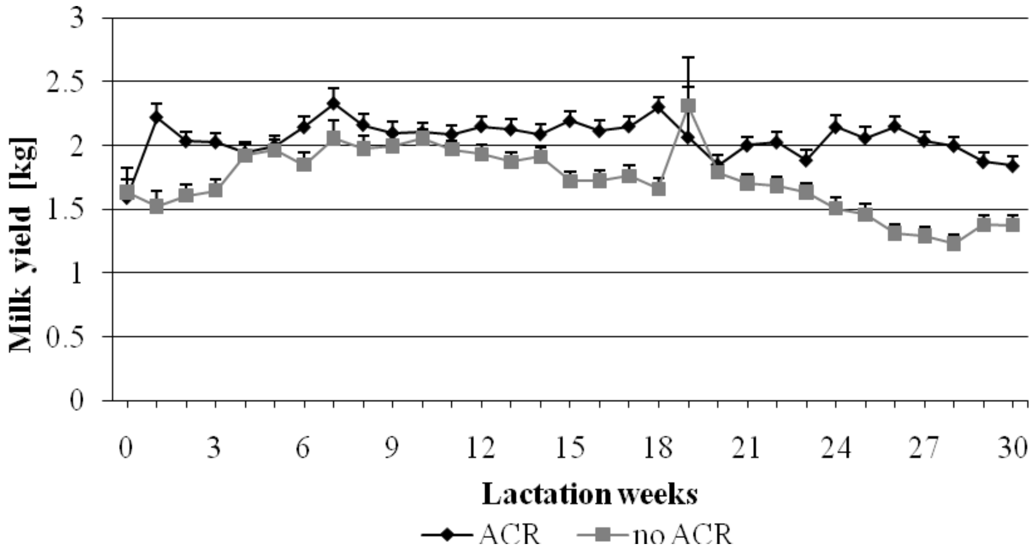

Figure 2. Lactation curves of the two groups involved in the field study

The two curves determined by Wood's equation (Figure 2) were both characterized by a good coefficient of determination (R^2). The curve describing the lactation of the ACR group showed a higher R^2 (84%) in comparison with the R^2 of the noACR group (60%), highlighting a greater uniformity of the ACR group in milk production throughout the whole lactation, also confirmed by the lower SEMs reported near the values for the lactation curve traits (Table 1).

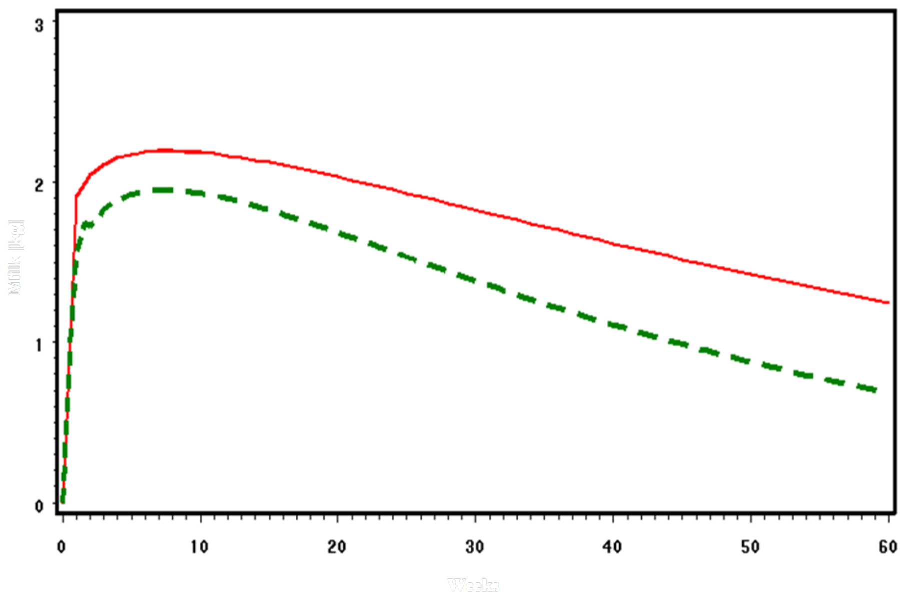

Figure 2. Milk yield lactation curve in ACR (solid line) and noACR (dashed line) groups performed through non linear regression of Wood equation.

Table 1. LS means and coefficient of determination of noACR and ACR groups for lactation curve traits

	Lactation curve[1] traits						
	a		b		c		
	Mean	SEM	Mean	SEM	Mean	SEM	R^2
noACR[2]	1.579[A]	0.092	0.210	0.037	0.028	0.003	60 %
ACR[2]	1.939[B]	0.053	0.119	0.018	0.013	0.001	84 %

[A,B] Means with different superscripts differ significantly (*P* < 0.001)
[1] "a" is a scaling factor to represent yield at the beginning of lactation, and "b" and "c" are factors associated witrh the inclining and declining slope of the lactation curve
[2] n = 12

The shape of the curves (Figure 2) determined by Wood's equation showed that the ACR group reached a higher lactation peak about two weeks later than the noACR group (9.2 vs. 7.5 weeks of lactation), but maintained a higher production throughout lactation.
Average peak production, calculated by Wood's curve parameters, was 2.24 kg/day for ACR group and 1.95 kg/day for noACR group ($P < 0.001$).
A higher value of parameter ***a***, which represents milk yield at the beginning of lactation, was recorded for ACR group (1.939 vs. 1.579; $P < 0.001$). Consequently at a higher ***a*** value, a lower value of parameter ***b*** was associated, which stands for the inclining slope of lactation. The declining slope of the lactation curve, decay rate ***c,*** higher for noACR group (0.028 vs. 0.013), was not significantly different between treated and control animals during the rest of lactation.
Mean 210-d actual milk yield was 434.84 ± 10.44 kg for ACR group and 362.017 ± 13.03 kg for noACR group. The higher SEM associated to the lower mean milk yield for the untreated goats confirmed further the higher variability of the daily milk production for the animals with manual removing of the milking unit at the end of milking.
The higher milk production registered for ACR group could be mainly due to the better coupling between the teats and the milking unit guaranteed over the entire milking by the innovative ACR system developed. It is reasonable to think that this system, working as a vertical stabilizer of the milking unit, avoided the folding and the straining of the teats during the progressive udder emptying, allowing to collect completely the cisternal fraction of milk. This hypothesis seems supported by the fact that oxytocin release in goats occurs immediately after the start of stimulation, causing a tendency for immediate decrease in milk flow rate after unit attachment (Bruckmaier *et al.*, 1994) and that, in contrast with cows in which less than 30% of the total milk yield volume is stored in the cistern within a normal milking interval (Ayadi et *al.*, 2003), in dairy goats the cisternal fraction accounts for up to 75% (Marnet and McKusic, 2001).
Another factor, though not investigated in this study, which may have contributed to increased milk production in goats managed by ACRs is the overmilking reduction. On the contrary, the extension of milking in the absence of milk flow, which typically occurs when milkers remove the milking units late, causes teat tissue congestion and injury (Isaksson and Lind, 1992). Overmilking for a long period has been shown to increase the incidence of intramammary infection (IMI) in dairy cows (Mein *et al.*, 1986) by compromising the teat end's ability to resist bacterial penetration to the mammary gland (Peterson, 1964), resulting in decreased milk production.

Conclusions

This study attempted to evaluate the ACRs effects on milk yield and lactation persistency in goat lactation.
A higher milk peak and a better persistency in milk yield was observed in goats subjected to the automatic cluster removal at a preset milk flow level in comparison with goats subjected to the manual removal of the milking group at the end of milking.
The better coupling between the teats and the milking unit guaranteed over the entire milking by the innovative ACR system developed and a potential overmilking reduction seem to be the key factors.

References

Ayadi M., Caja G., Such X., Knight C.H. 2003. Use of ultrasonography to estimate cistern size and milk storage at different milking intervals in the udder of dairy cows. J. Dairy Sci. 70:1-7.

Bruckmaier R.M., Ritter C., Schams D., Blum J.W. 1994. Machine milking of dairy goats during lactation: udder anatomy, milking characteristics, and blood concentrations of oxytocin and prolactin. J. Dairy Res. 61:457-466.

Guidobono Cavalchini A., Silva G., Zaninelli M., Tangorra F.M. 2004. Dispositivo per lamungitura automatica di ovicaprini. Domanda di brevetto n. MI2004A002357.

Isaksson A., Lind O. 1992. Teat reactions in cows associated with machine milking. Journal of Veterinary Medicine. 39:282-288.

Magliaro A. L, Kensinger R. S. 2005. Automatic Cluster Remover Setting Affects Milk Yield and Machine-On Time in Dairy Cows. J. Dairy Sci. 88:148-153.

Marnet P.G., McKusic B.C. 2001. Regulation of milk ejection and milkability in small ruminants. Livest. Prod. Sci. 70:125-133.

Mein G. A., Brown M. R., Williams D. M.. 1986. Effects on mastitis of overmilking in conjunction with pulsation failure. J. Dairy Res. 53:17-22.

Neijenhuis, F., H. W. Barkema, H. Hogeveen, and J. P. T. M. Noordhuizen. 2000. Classification and longitudinal examination of callused teat ends in dairy cows. J. Dairy Sci. 83:2795-2804.

Neijenhuis, F., H. W. Barkema, H. Hogeveen, and J. P. T. M. Noordhuizen. 2001. Relationship between teat-end callosity and occurrence of clinical mastitis. J. Dairy Sci. 84:2664-2672.

Peterson K. J. 1964. Mammary tissue injury resulting from improper machine milking. Am. J. Vet. Res. 25:1002.

Rasmussen, M. D. 1993. Influence of switch level of automatic cluster removers on milking performance and udder health. J. Dairy Res. 60:287-297.

Stewart, S., S. Godden, P. Rapnicki, D. Reid, A. Johnson, and S. Eicker. 2002. Effects of automatic cluster remover settings on average milking duration, milk flow, and milk yield. J. Dairy Sci. 85:818-823.

Tangorra F.M., Zaninelli M., Mercandino L. 2007. Effect of automatic cluster removal on parlor performance and unit cost of milking in dairy goats. In: Advances in labour and machinery management for a profitable agriculture and forestry, Nitra, Department of Machines and Production Systems - Faculty of Agricultural Engineering, Slovak University of Agriculture, 2007. ISBN 978-80-8069-923-9.

Tangorra F.M., Zaninelli M., Cigalino G., Savoini G. 2008. Effects of automatic cluster removal on dairy goats milking. In: International Dairy Federation special issue. ISSN 1025-8515 - 0801: Pt. 2(2008), 203-205.

Wood, P.D.P. 1967. Algebraic model of the lactation curve in cattle. Nature, 216:164-165.

Topic 6
"Open topics"

Poster Presentation

Preliminary Results about the Energy Saving Applied to the Decanter Centrifuge Used in Olive Oil Extraction

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Abstract
This paper illustrates the simulation, the experimental measurements and the analysis of the optimal coupling between a decanter centrifuge used for olive oil extraction in the olive oil mills and a the three-phase induction motor. The simulation offers the vantage of the reduction of the costs of purchasing various kind of motors to be tested. In this simulation different typologies of coupling between a driving electronic variable frequency driver, an alternating current electric induction motors and the decanter centrifuge were examined. Results show that the motor oversizing is necessary to improve the efficiency of the machine but the oversizing is limited by the asymptotic behaviour of the specific energy consumption with respect to the induction motor rated mechanical power. When comparing the "variable frequency" driving mode to the "field oriented control" driving mode, the gain in the overall energy consumption over the entire 40 days period of the campaign in the olive oil mill was between 7.7% and 8.2%, and when comparing the most common direct to electric line "STAR" connection driving mode to the "field oriented control", the gain was between 2.9% and 3.9% .

Keywords: induction three-phase asynchronous motor, variable frequency drive, simulink modelling, efficiency

Introduction
An important facet of sustainability is energy consumption. Sustainable process is therefore an efficient one, and the evaluation of energy efficiency is very important; once the energy efficiency of a process has been measured and benchmarked, control or design actions may be taken to improve the process.
Nowadays electric motors have broad applications in such areas as industry, business, public service and household electrical appliances, powering a variety of equipment including wind blowers, water pumps, compressors and machine tools (Saidur, 2010). Motor-driven systems account for approximately 65% of the electricity used by EU industry (Anon, 2004), but recently there has been a growing concern about energy use and its adverse impact on the environment.
It is very important to select an electric motor of suitable power to work efficiently. Motor oversize is one of the most frequently misapplication encountered and difficult to be fixed (Da Costa Bortoni, 2009). Oversizing accounts for a considerable share of the efficiency problems often found in motor applications. In general, motors are chosen in big capacities to meet extra load demands. Big capacities cause motors to work inefficiently at low load. Normally, motors are operated more efficiently at 75% of rated load and above. Correct sizing of electric motors is critical to their efficient operation, since oversized motors tend to exhibit poor power factors and lower efficiencies (Beggs, 2002). Depending on size and speed, a typical standard motor may have a full load efficiency between 55% and 95%. Generally, the lower the speed, the lower the efficiency, and the lower the power factor.

Energy can be saved in different ways for different industrial energy using machineries with different energy savings strategies. These strategies are broadly classified in three ways (Saidur, 2010):

- using regulations (voluntary, mandatory, mixed, standards, labels, education, soft loan, incentives);
- with the application of technology (variable speed drives (VSD), power factor improvement, new technology);
- by housekeeping (maintenance, switching of, reduce standby losses, auditing).

Switching to energy-efficient motor-driven systems can save Europe up to 202 billion kWh in electricity use, equivalent to a reduction ofs10 billion per year in operating costs for industries. It was reported that a reduction of 79 million ton of CO2 emissions (EU-15), or approximately a quarter of the EU’s Kyoto target is achievable using energy-efficient motors. Energy savings by technology includes use of VSDs to match the load requirements and capacitors to reduce losses thus improving motor power factor (Elliot, 2007).
In about 25% of the applications that induction motors are used, there is no need to operate the motor at full load (Leonard Abbott III, 2006). For example, in the water supply industry, constant speed drives will operate the pump at 100% of the motor rated speed, then the valves are placed in the pipeline and are adjusted to restrict the flow of water. In other industries, reduction gears are placed after the electric motor to reduce the speed or torque. The cost of valves, gears, and excess electric energy can be an additional unnecessary cost once output power is clamped down (Leonard Abbott III, 2006). Constant speed motor starters cannot adjust their speed, so that anytime there is need for the speed of a motor to operate.
Variable frequency drives provide continuous control, matching motor speed to the specific demands of the work being performed (APEC, 2008; Jayamaha, 2008). Variable-frequency drives are an excellent choice for adjustable speed drive users because they allow operators to fine tune processes while reducing costs for energy and equipment maintenance.
Adjustable speed motors conserve energy by operating motors at levels only necessary for the particular task at a given time and can provide significant savings in energy usage and costs.
Qureshi and Tassou, 1996, reviewed the VSD in refrigeration application to reduce energy uses. Variable-frequency drives (VFD) are routinely used to vary a pump and fan speed in heating, ventilating and air conditioning of buildings.
Another example of the use of VFDs was in the pumping of machine coolant at an engine plant. Pressure at the pumps was reduced from 64 psi to 45 psi, average flow cut in half, and power usage reduced by over 50% with no adverse effect on part quality or tool life (Price et al., 1989). Reducing the coolant system pressure also reduced the misting of the coolant, reducing the ventilation requirements and cleaning costs. VFDs can also be used in draft fans on coal fired boilers, instead of dampers. The average electricity savings depend on boiler load, but will typically exceed 60% annually (Price et al., 1989).
Almeida et al., 2003, estimated that energy savings for motors using VFDs for food, beverage and tobacco industries amounts to 8.0 TWh.
Cini et al., 2008, estimated the electric energy consumption at small and medium size olive oil mills placed in Tuscany Region (Italy), referring to the overall electric power employed in each process step, including submitted equipment (pumps and fans).
In a typical olive oil mill plant motors are used to drive process equipment (olive crushers, kneading machine, pumps, centrifugal extractors).

During an entire production campaign the electric consumption amount could be very important especially taking into account that the decanter centrifuges are run several hours in a day. Normally the electric motor is oversized with respect to the required power to run the decanter centrifuge, this is done to ensure a minimal delay of time to run the decanter at its nominal speed, but this also involves that the driving motor is run to one fraction of its nominal power with lesser efficiency. The aim of this work is to establish, by means of both a simulation and experimental measurements, the relationship existing between overall efficiency and coupling between an inverter driven asynchronous electric motor and the decanter centrifuge when operating at an olive oil mill. In fact it has shown (Zakharov, 2008) that the use of simulation programs for induction motors is relevant in engineering problems.

Materials and methods

The machine used was a decanter centrifuge BABY-1 from "Pieralisi", with an operating throughput of about 5000 kg/h, equipped with a 5.5 kW nominal mechanical power (M1) asynchronous electric three-phase induction motor (IM) from "ABB", the motor was driven by an electronic three-phase inverter, i.e. an electronic variable frequency driver (VFD), whose efficiency was about 0.95. The Matlab Simulink software (using the SimPowerSystems toolbox) from MathWorks was used to simulate the physical system. The use of other three induction motors (named as M2, M3 and M4) was supposed with respectively a 4.0 kW, 3.0 kW and 2.2 kW nominal mechanical power in order to investigate the optimal coupling between motor and decanter centrifuge. Several hypothesis were simulated, from the case of oversized IM to the case of overloaded IM; testing various couplings between the four motors and the decanter centrifuge and between the electric line and the four motors. The characteristics of the real motor (see tab.1) and of the decanter (see tab.2) were measured on field and entered into the model while for the induction motor M2, M3 and M4 characteristics were taken from the datasheet by ABB. Moreover a time table provided by a real olive oil mill was used to simulate the activity time of the motor coupled to the decanter (see fig.1); from data was observed that, considering the overall working time per day, for about 6% of this time the decanter was run unloaded while for the remaining 94% of working time the decanter was run loaded.

In order to evaluate the possible energy saving when the decanter is operated at the olive oil mill, different typologies of coupling between the driving electronic VFD, the alternating current (AC) electric induction motors (IM) and the decanter centrifuge (DEC) were examined. The examined coupling cases, for each of the four motors M1, M2, M3 and M4, were the following:

C1. VFD (efficiency of 0.95) driving the IM at variable frequency and sinusoidal line voltage (VARF), speed variation with fixed gear ratio (efficiency of 0.97) but variable with the inverter frequency in order to attain the decanter nominal working speed, working decanter speed of about 4916+/-5% rotations per minute (RPM), in this case was calculated the overall IM efficiency and the active power sunk by the IM from the electric line;

C2. IM directly connected to the electric line with a "star" connection (STAR), speed variation with fixed gear ratio of 1.7365 (efficiency of 0.97), even in this case was calculated the overall IM efficiency and the active power sunk by the IM from the electric line;

C3. IM directly connected to the electric line with a "delta" connection (DELTA), speed variation with fixed gear ratio of 1.7365 (efficiency of 0.97), in this case was calculated the overall IM efficiency and the active power sunk by the IM from the electric line;

C4. VFD driving the IM with a direct torque control algorithm (DTC) with sensor feedback control of IM speed, speed variation with fixed gear ratio of 1.7365 (efficiency of 0.97), working IM speed set-point of 2831 RPM, in this case was calculated the overall VFD+IM efficiency and the active power sunk by the VFD+IM from the electric line;

C5. VFD driving the IM with a field oriented control algorithm (FOC) with sensor feedback control of IM speed, speed variation with fixed gear ratio of 1.7365 (efficiency of 0.97), working IM speed set-point of 2831 RPM, in this case was calculated the overall VFD+IM efficiency and the active power sunk by the VFD+IM from the electric line.

The DTC algorithm is one of the methods used in VFD to control the torque (and directly the speed) of three-phase IM. This involves an estimate of the motor's magnetic flux and torque based on the measured voltage and current of the motor. It is one form of on-off feedback control system. (Lai and Chen, 2001; Casadei et al., 2002).

The FOC algorithm, based on the control of the fed current to the machine, is very common in IM control due to both its low cost and ability to control the motor speed more efficiently if compared to other control systems. Although the vector control algorithm is more complicated than the DTC, the algorithm is not needed to be calculated as frequently as required by the DTC algorithm. In a typical industrial application, the improved dynamic behaviour enabled by FOC also enables designers to size the motors optimally, rather than oversize the motor to meet the transient requirements. A smaller motor also runs at a higher fraction of its power rating, meaning that the resulting operating point is suited to provide a better efficiency. (Casadei et al., 2002).

Finally the simulated results at steady state for each case from C1 to C5, with decanter centrifuge loaded and unloaded were analysed, using the Matlab software. Results of analysis were applied to the time table, conjecturing a 40 days campaign time. Assumption were made about the dilution ratio (mass of added process water related to the mass of olive oil paste) considered 0.3 and about the decanter full throughput capacity considered equal to 5000 kg/h; the final results were the energy consumptions per olive oil unit mass.

Table 1. Electric induction motors M1, M2 M3 and M4, measured and calculated characteristics to be computed by the Matlab's "simulink" model.

	M1 (5.5 kW)	M2 (4.0 kW)	M3 (3.0 kW)	M4 (2.2 kW)
Electrical Active Power (kW)	6.4	4.66	3.5	2.66
Line Voltage (Vrms)	400	400	400	400
Line Current (Arms)	10.6	7.9	6.2	4.6
Frequency (Hz)	50	50	50	50
CosPhi	0.871	0.851	0.815	0.835
Poles Pairs	1	1	1	1
Efficiency	0.859	0.858	0.857	0.827
Mechanical Power (kW)	5.5	4.0	3.0	2.2
Torque (N.m)	18.454	13.24	9.855	7.269
Shaft RPM	2846	2885	2907	2890
Slip (%)	5.133	3.833	3.100	3.667
F (friction factor)	0.0005	0.0005	0.0005	0.0005
J (Inertia) (kg.m^2)	0.01241	0.00671	0.0042	0.00163
Motor Type	Squirrel-cage	Squirrel-cage	Squirrel-cage	Squirrel-cage

Table 2. Decanter centrifuge "Baby-1" measured and calculated mechanical characteristics to be computed by the Matlab's "simulink" model.

Drum Operating RPM	Speed Variation	Speed Variation Ratio	Speed Variation Efficiency	Motor Shaft Operating RPM	Differential Scroll RPM	F (friction factor) (N.m.s)	J (Inertia) (kg.m^2)	Additional Torque when Loaded (N.m)
4916	Pulley with two toothed drive belts	1.7365	0.97	2831	12	0.009714	2.3410	1.8025

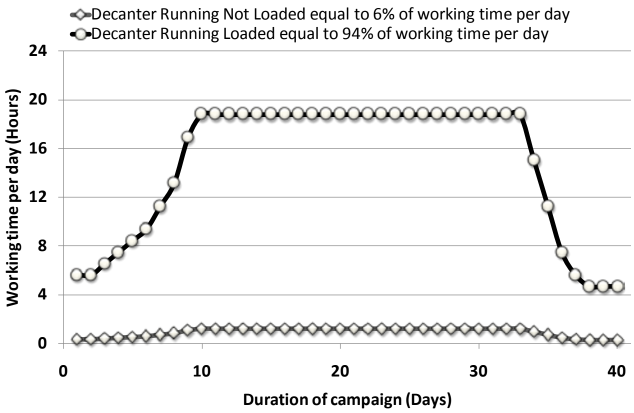

Figure 1. Time table recorded from a real olive oil mill to simulate the activity of the motor coupled to the decanter when used for the olive oil extraction at a real mill over a 40 days campaign.

Results and discussion

The characterising results, in order of importance, for each examined case are:

- the active power in kW (APOW) absorbed by the electric line;
- the overall efficiency (EFF);
- the decanter running speed (DSPD) in RPM.

The obtained simulation's results are reported in tab.3, the energetic results are reported in tab.4 .

The first consideration is that the IM M4 in case C3 doesn't start under a loaded decanter because the required torque is greater than the breakdown motor torque. The use of the VFD enhances the starting capability of the IM and also permits the control of the decanter centrifuge running speed (see DSPD into tab.2).

In fig.2 are reported the specific energy consumption with regard to the overall processed product vs. the IM rated mechanical power (IMRMP).

From fig.2 arises that the DELTA driving mode brings a linear correlation between ESPEC and IMRMP in the tested range of power; moreover for IMRMP values lower than about 4.750 kW the figure 2 shows an ESPEC value greater than other tested cases.

The VARF driving mode (see fig.2) shows an asymptotic trend at high IMRMP, but also in this case the ESPEC values are greater than the other tested cases.

The STAR and DTC driving mode are quite similar (see fig.2) and again show the asymptotic trend at high IMRMP, however for the IMRMP of 2.2 kW their difference in ESPEC is remarkable. The FOC driving mode shows the minimal ESPEC values and therefore represents the best driving mode for the IM in our tested cases (see fig.2). Again we can see the asymptotic trend of the ESPEC value at high values of the IMRMP.

Table 3. Obtained results from simulation of various couplings between decanter centrifuge and IM and between IM and electric line: for each of the four IM and for the cases previously depicted are only shown the characterising results as the active power (APOW) in kW absorbed by the electric line, the overall efficiency (EFF) and the decanter running speed (DSPD) in RPM.

	M1 (5.5 kW)			M2 (4.0 kW)			M3 (3.0 kW)			M4 (2.2 kW)		
	APOW (kW)	EFF	DSPD (RPM)	APOW (kW)	EFF	DSPD (RPM)	APOW (kW)	EFF	DSPD (RPM)	APOW (kW)	EFF	DSPD (RPM)
UNLOADED												
C1 (VARF) (max EFF)	2.034	0.845	5136	2.041	0.841	5134	2.088	0.818	5123	2.118	0.791	5073
C1 (VARF) (min APOW)	1.999	0.819	5014	1.574	0.072	1321	2.086	0.81	5094	2.118	0.791	5073
C2 (STAR)	1.941	0.885	5137	1.944	0.883	5135	1.999	0.855	5124	2.012	0.833	5073
C3 (DELTA)	1.900	0.862	5013	1.964	0.826	4991	2.025	0.79	4955	2.374	0.555	4498
C4 (DTC)	1.853	0.849	4916	1.867	0.843	4917	1.924	0.817	4914	2.004	0.787	4921
C5 (FOC)	1.844	0.854	4917	1.837	0.857	4918	1.902	0.827	4914	1.924	0.817	4913
LOADED												
C1 (VARF) (max EFF)	3.149	0.851	5092	3.201	0.835	5086	3.28	0.81	5066	3.461	0.743	4966
C1 (VARF) (min APOW)	3.149	0.846	5074	3.201	0.835	5086	3.28	0.81	5066	3.461	0.743	4966
C2 (STAR)	3.001	0.893	5093	3.042	0.879	5087	3.126	0.851	5068	3.29	0.78	4960
C3 (DELTA)	3.047	0.819	4874	3.306	0.728	4768	3.483	0.673	4687	Doesn't start	Doesn't start	Doesn't start
C4 (DTC)	2.986	0.848	4916	3.025	0.837	4916	3.122	0.81	4915	3.425	0.739	4917
C5 (FOC)	2.894	0.874	4916	2.924	0.866	4919	3.025	0.836	4915	3.198	0.793	4924

Table 4. Obtained results from simulation of various coupling between decanter centrifuge and IM and between IM and electric line: for each of the four IM and for the cases previously depicted are shown the specific energy consumption (ESPEC) whit regard to the overall processed product, the overall energy consumption (ETOT) with regard to the entire campaign of 40 days, the variation percent (VAR) of the overall energy consumption with regard to the minimum energy consumption case (for witch VAR=0.0) as calculated by the Matlab's "simulink" model.

Hours Loaded	589.38			Hours Unloaded			37.62					
Overall processed product (kg)				226685								
	M1 (5.5 kW)			M2 (4.0 kW)			M3 (3.0 kW)			M4 (2.2 kW)		
	ESPEC (Wh/kg)	ETOT (kWh)	VAR (%)	ESPEC (Wh/kg)	ETOT (kWh)	VAR (%)	ESPEC (Wh/kg)	ETOT (kWh)	VAR (%)	ESPEC (Wh/kg)	ETOT (kWh)	VAR (%)
C1 (VARF) (max EFF)	8.526	1933	8.2	8.661	1963	8.7	8.875	2012	7.8	9.350	2120	7.7
C1 (VARF) (min APOW)	8.520	1931	8.1	8.584	1946	7.9	8.874	2012	7.8	9.350	2120	7.7
C2 (STAR)	8.125	1842	3.6	8.232	1866	3.9	8.459	1918	3.3	8.888	2015	2.9
C3 (DELTA)	8.238	1867	4.9	8.922	2022	11.4	9.392	2129	12.9	-	-	-
C4 (DTC)	8.071	1830	3.0	8.175	1853	3.3	8.437	1912	3.0	9.238	2094	6.5
C5 (FOC)	7.830	1775	0.0	7.907	1792	0.0	8.181	1854	0.0	8.634	1957	0.0
Percent mechanical loading with decanter loaded with regard to full rated load of IM (%)	46.02			63.28			84.37			115.05		

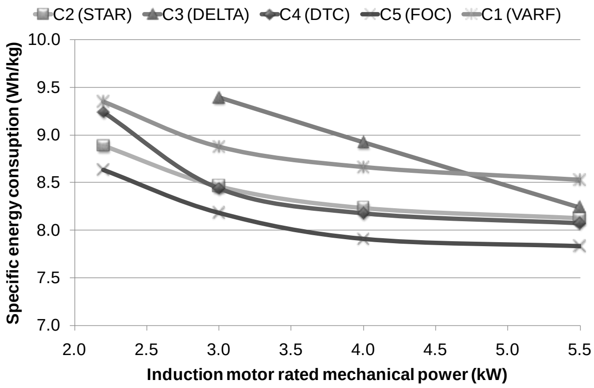

Figure 2. Specific energy consumption with regard to the overall processed product vs. the IM rated mechanical power, as obtained from simulation of various coupling between decanter centrifuge and IM and between IM and electric line for each of the four IM and for the cases previously depicted.

Tab.4 shows that the asymptotic trend of the ESPEC at high values of the IMRMP is also related to the mechanical motor loading percent (MMLP); in fact low values of MMLP bring to low ESPEC values and thus to a best overall process efficiency in terms of power consumption. This can enforce the opinion that heavily oversizing the IM leads to improve the energy saving of the process but this should be compared with the asymptotic behaviour of the ESPEC. At higher IMRMP values an increase of the IMRMP itself brings to a decrease of the ESPEC that can be negligible when compared with the biggest costs for purchasing the IM and VFD, so further investigations are required to correctly asses a method for the induction motor oversizing. From tab. 4 arises that comparing the VARF driving mode to the FOC, the gain in the overall energy consumption over the entire 40 days period of the campaign was between 7.7% and 8.2%, while comparing the most common direct to electric line STAR driving mode to the FOC, the gain was between 2.9% and 3.9% .

Conclusion

In this simulation different typologies of coupling between a driving electronic variable frequency driver, an alternating current electric induction motors and the decanter centrifuge were examined. From the trials arises that the motor oversizing is a need in order to improve the efficiency of the process but the oversizing is limited by the asymptotic behaviour of the specific energy consumption with respect to the induction motor rated mechanical power. In fact increasing the induction motor rated mechanical power brings to a decrease of the specific energy consumption that can be negligible if compared with the biggest costs necessary to purchase both a powerful induction motor and the variable frequency driver. When comparing the VARF driving mode to the FOC, the gain in the overall energy consumption over the entire 40 days period of the campaign in the olive oil mill was between 7.7% and 8.2%, and when comparing the most common STAR driving mode to the FOC, the gain was between 2.9% and 3.9% . Further investigations are required to correctly asses a method for the induction motor oversizing.

References

Almeida A.T., Fonseca P., Bertoldi P., 2003. "Energy efficient motor systems in the industrial and in the services sectors in the European Union: characterization, potentials, barriers and policies", Energy, 28: 673-690.

APEC, 2008. Electric Motors-Alignment of Standards and Best Practice Programmes within APEC, Final Report.

Beggs C., 2002. "Energy management and conservation". Elsevier Ltd; 2002.

Casadei D., Profumo F., Serra G., Tani A., 2002. "FOC and DTC: Two Viable Schemes for Induction Motors Torque Control". IEEE Transaction on Power Electronics, vol. 17, n. 5: 779-787.

Cini E., Recchia L., Daou M., Boncinelli P., 2008, "Human health benefits and energy saving in olive oil mills", International Conference "Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems", 15-17 September 2008, Ragusa, Italy.

Da Costa Bortoni E., 2009, "Are my motors oversized", Energy Conversion and Management, 50: 2282-2287.

Elliot N.R., 2007. "Impact of proposed increase to motor efficiency performance standard". ACEEE.

Jayamaha L., 2008. "Energy efficient building systems". McGraw Hill Publisher.

Kestelyn X., Semail E., Hautier J. P., 2004. "Multi-phase system supplied by SVM VSI: A new fast algorithm to compute duty cycles," European Power Electronics and drives Journal, vol. 14, n. 3: 25-31.

Lai Y.-S., Chen J.-H., 2001. "A New Approach to Direct Torque Control of Induction Motor Drives for Constant Inverter Switching Frequency and Torque Ripple Reduction". IEEE Transaction on Energy Conversion, vol. 16, n. 3: 220-227.

Leonard Abbott III, 2006. "Power quality and cost analysis of industrial electrical distribution systems with adjustable speed drives". MS Thesis, California State university, USA.

Price A., Ross M.H., 1989. "Reducing industrial electricity costs – an automotive case study". The electricity Journal, July: 40-51.

Qureshi T.Q., Tassou S.A., 1996. "Variable-speed capacity control in refrigeration systems". Applied Thermal Engineering, 16(2): 103-113.

Saidur R., 2010. "A review on electrical motors energy use and energy savings". Renewable and Sustainable Energy Reviews, 14: 877-898.

Zakharov A.V., 2008, "Software Simulation and Analysis of Transient Processes in Engineering Problems of Induction-Motor Design", Russian Electrical Engineering, 79l, 8-12.

Comparison of Two Heating System for Tropical Plants Production in Mediterranean Conditions

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Abstract

Protected productions in Mediterranean climates require suitable design of greenhouses and environmental control equipment. In Italy most greenhouse structures and equipment have been designed mainly in periods with low energy prices thus they are often very traditionally manufactured and low performing from an energetic point of view. Renewing the structures and adopting sophisticated inside environment control systems is generally very expensive but, overall, these additional investments not always allows increasing the grower returns.

Moreover, in the case of very exigent tropical plants production, it is not possible to find compromises between the agronomic performance of the greenhouse production system and the corresponding cost management. The replacement of traditional diesel oil fuelled boiler with wood biomass one is, at present, a feasible and cost-effective option where the conditions are favorable.

A study case was analyzed considering a commercial installation located in Liguria Region, Italy, specialized in moth orchids (*Phalaenopsis Spp.*) production. The study case shows a comparison of the annual fuel consumption and the relevant costs and management tasks with the two heating systems.

It was conducted an economic comparison between the use of diesel and the use of biomass through a software that has interpreted the real data and simulated future consumption. It was finally verified the simulated results with data obtained from the greenhouse in the following year with the use of biomass.

It was possible to conclude that the replacement of traditional diesel oil fuelled boilers with wood biomass ones is a feasible and cost-effective solution given the present situation and considering the predictable energetic evolution.

Keywords: greenhouses, energy saving, alternative energy use, internal microclimate, heating system, logistic

Introduction

The growing importance of tropical plants production as moth orchids (*Phalaenopsis Spp.*) (Griesbach, 2002) is taking place also in Italy but requires, in despite of its Mediterranean climatic surroundings, very high input levels (both agronomic and energetic) to satisfy the high-demanding growing cycle needs (Lee, 2002). Actually, in nature moth orchids can be found throughout the entire tropical Asian region where they grow at daytime temperatures of 28-35°C and nighttime temperatures of 20-24°C (Blanchard and Runkle, 2005). Fairly high relative humidity levels have to be maintained in the range between 60 and 80% (Arditti and Pridgeon, 1997).

Moreover the plants need shaded conditions with light intensities ranging from 75 to 214 (max 300) $mmol \cdot m^{-2} \cdot s^{-1}$ photons, at plant level, following the cultivation phase (Runkle, 2007). Replicate this environment in protected conditions in the Mediterranean could be very

expensive. Moreover, recent increases in fuel prices has forced producers to savings measures.
The reduction of inputs of energy is not always possible or sufficient to restore profitability. Investing in new greenhouses at low energy is not always feasible due to high initial costs. An optional strategy could concern the use of alternative and cheaper fuels (Garcia et al., 1998; Chau et al., 2009) by simply converting the central boiler.
Liguria Region, even if situated in the Northwest part of the Country, has a mild temperate, Mediterranean climate thus developing a strong position in specialized ornamental and horticultural cultivations.
In the present work, the economic performances of a greenhouse plant heated by a hot water pipes system, converted form diesel oil to biomass central heater is presented.

Methods
A greenhouse (C.&G. floricoltura) located in Liguria Region, Italy, specialized in moth orchids (Phalaenopsis Spp.) production has been considered. The greenhouse plant was located on the plain of Albenga. The greenhouse is very traditional for the Region and consists of 15 to 20 years old steel, single glass gutter-connected frame, 3 m maximum height and 4,124 m^2 total surface (9,699.9 m^3) articulated in 6 productive units (PU1 to PU6) (Fig. 1).

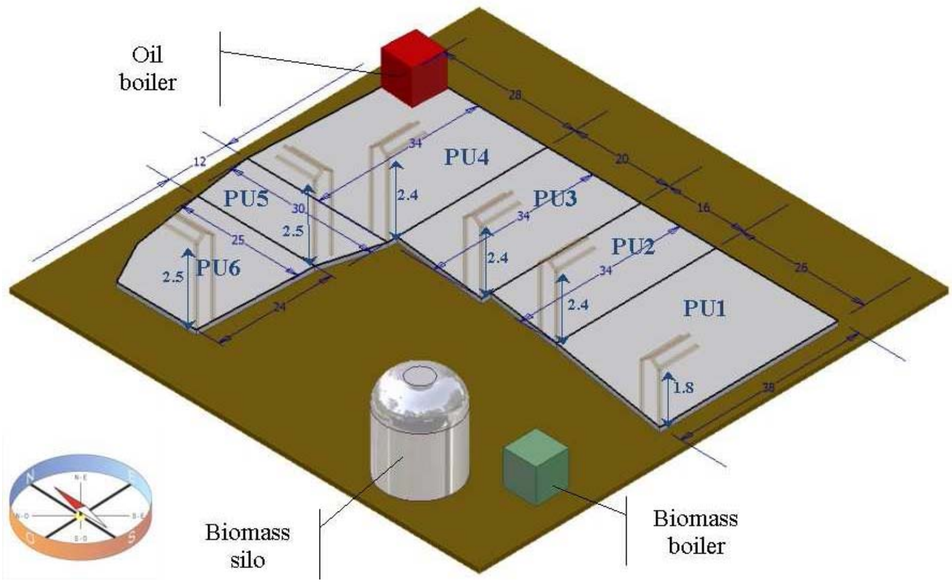

Fig. 1. Scheme of the greenhouse arrangement and location of the productive units (PU) and boilers (the dimensions are expressed in meters; greenhouses heights are not in scale).

The PU have been constructed in different periods and are slightly different in overall dimensions and microclimate management. The heating schedule, planned for 12 months·$year^{-1}$ heating, is reported in table 1.

Table 1. The heating schedule in the different PU.

PU	Minimum temperature regimes
1	15-18°C
2	18-20°C
3	18-20°C
4	23-26°C
5	23-26°C

To improve both the thermal insulation and the light intensity control, a white, semitransparent foamed plastic coat, 3 mm thick, was fixed under the roof. The conventional heating system was based on a central diesel oil boiler 1.16 MWt power and an under-bench hot water pipe system network.

A year-round (2007) monitoring of the monthly oil consumption was performed and the number of tank replenishment was recorded. Because of the high price level oscillations of the considered period, two levels (min. and max.) of diesel oil charge were retained. Considering that any investment focused in oil saving was evaluated unfeasible in comparison with the use of a cheaper fuel, a biomass boiler was added to the conventional one without any changing in the frame structure and microclimate management.

At the end of 2007 a multi-fuel wood biomass boiler 1.39 MWt power (mod. Spitfire manufactured by Metalref, Pistoia, Italy) complete with biomass silo and control accessories, was fitted in the system without modifying any other structural element. The biomass boiler was connected to the existing hot water pipe systems by means of 125 mm diameter, high performances, pre-insulated, district heating supply type, thermal pipes (mod. Rauthermex, manufactured by Rehau, Erlangen, Germany).

Moreover, to further cut water heat dispersion, a reduced number of pipe joints was used. An experimental phase to adjust the biomass-based system was performed in December 2007. A year-round (2008) monitoring of the monthly biomass consumption was performed and the silo replenishment was recorded. No changes were adopted for the microclimate management and controls given the specific requirements of the plants and the standard equipment of the grower.

The biomass used was mainly based on wood chips and sawdust pellets. A small amount (4.6% on annual wet weight basis) of other biomasses (coconut and hazelnut shells, grape seeds, olive-stones) was used mainly for the purpose of testing the boiler.

The wood chips (provided by the Benso Group, Savona, Italy) came from FSC (Forest Stewardship Council) certified forests located in the Bormida Valley at the surrounding mountain area characterizing the Northern side of this Region, at distances <40 km.

This oil-to-biomass conversion has been the first accomplished on the plain of Albenga and, given the rich wood availability of the district, it could represent a strong reference for the growers of the area.

Estimation of the energy needs of the greenhouse given the variable year-to-year weather conditions and in order to produce comparable figures between the two considered years and to provide considered indications for the district, the free decision support system (DSS) Virtual Grower 2.0 (Frantz, 2008) was used to estimate the energy demand of the greenhouse in average steady conditions.

The mentioned real dimensions, materials and set ups of the studied greenhouses were introduced in the computer program accepting the software assumptions; only the temperatures of the environment outside the greenhouse were adapted to the Albenga weather conditions referring to the Regional database.
Considering the medium-low airtight closure of the greenhouses, a conversion efficiency coefficient nh for the process was considered to be 0.51; the assumed number of air changes per hour ranged from 0.5 to 0.9 h-1 depending on the greenhouse PU.

Results

From values recorded in the monitored period was elaborated the montly cost required for heating by boiler with diesel (Fig. 2).

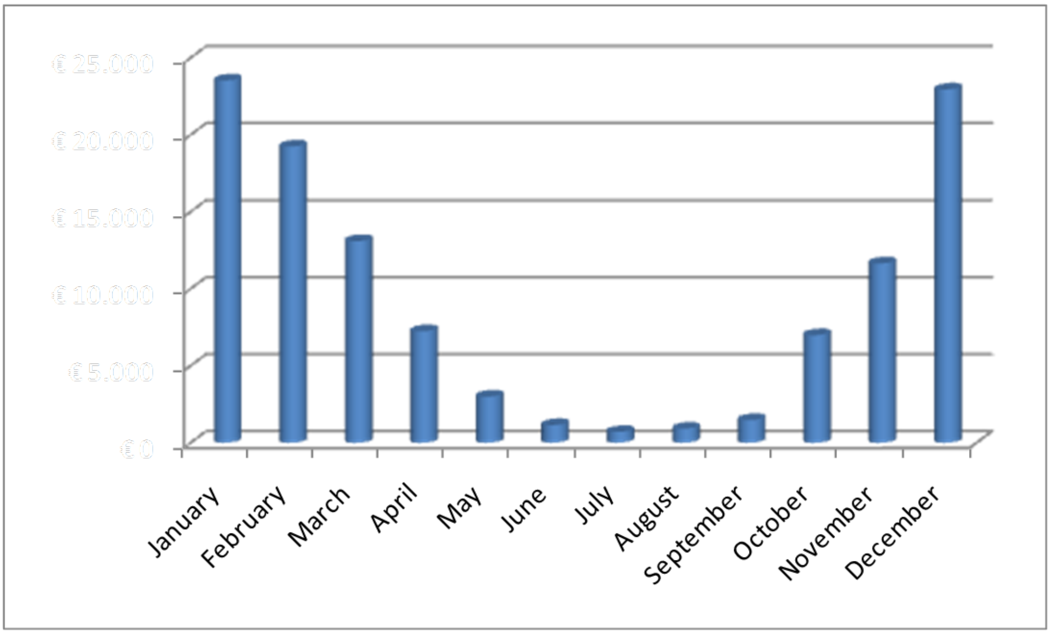

Fig. 2. Heating cost released into the greenhouse in 2007 by diesel oil.

The mean energy consumption per unit floor area was 44.6 W×m^{-2} ranging from maximum 81.0 W·m^{-2} (February) to minimum 7.0 W·m^{-2} (July). The number of tank replenishments depends upon the volume of the tank; in the considered case a 15.0 m^{3} tank was used requiring 10 replenishments per year.
To provide such levels of energy, the 2007 diesel oil consumption resulted 126,000 kg ranging from 1,680 kg·month^{-1} in July and 18,480 kg×month^{-1} in January with a specific annual cost of 23.6 to 27.3 €·m^{-2} following the price applied in the considered period (0.76 to 0.89 €·kg^{-2}).
This cost depends on the energy released in the greenhouse that couldn't be reduced in order to guarantee the optimal conditions for such plants as Orchids.
Based on the known results, collected in 2007, it was possible to perform simulations with a dedicated software in order to ensure consistency of values in terms of energy requirements and can make predictions for next year by proposing fuel alternatives.
The simulations were carried out with the Virtual Grower 2.0 that requires input data about the materials and layout of the greenhouse and cultural programming. In this case the

structural changes were not included, nor the production cycle. Then set points remained the same for two years to process. The only factor that was changed was the kind of fuel. In particular it was considered the pellet and chip which characteristics are given in Table 2.

Table 2. Main characteristics considered for the fuels used in the case study.

Fuel	Fuel Characteristics		
	Mass energy density ($MJ \cdot kg^{-1}$)	Unit price ($€ \cdot kg^{-1}$)	Specific price ($€ \cdot MJ^{-1}$)
Diesel oil	40.9	0.88	0.02
Wood chips (67% DM[1])	8.9	0.08	0.008
Sawdust pellet (90%DM[1])	18.8	0.15	0.009

[1]DM=dry matter

Calculations from Virtual Grower 2.0 simulation seem to give better results with chips and pellets (Fig. 3).

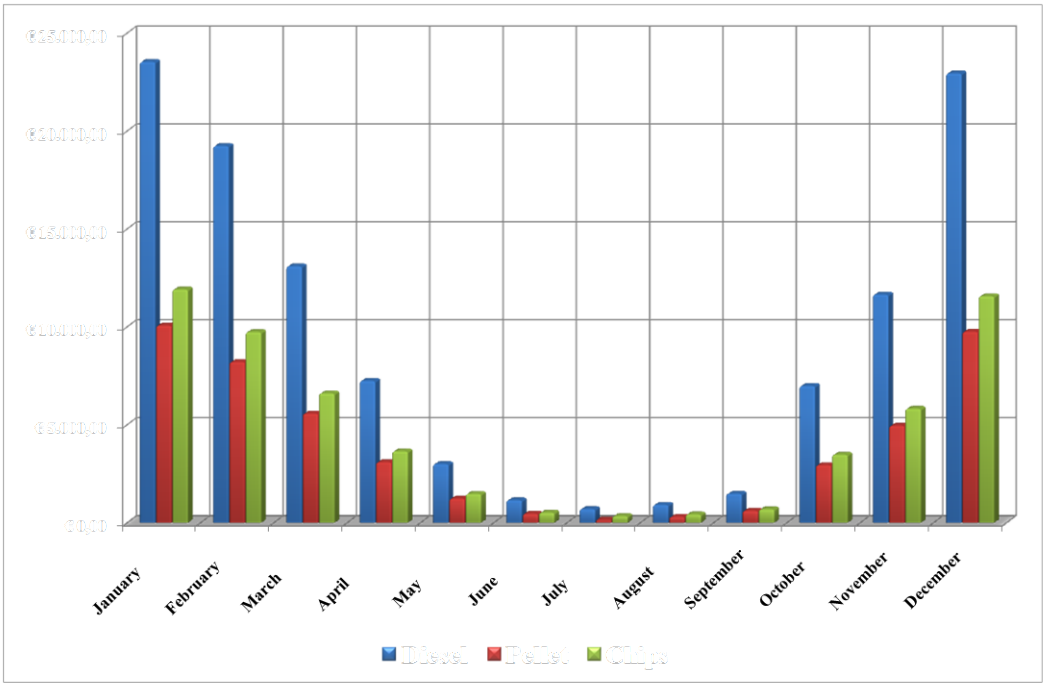

Fig. 3. Simulated pellet and chips costs and diesel costs to predict the 2008.

After the installation of the biomass boiler, the 2008 fuel consumption was recorded (Fig. 4). The biomass boiler was fed with wood chips, sawdust pellets and other biomasses depending on the market most convenient price. The annual biomass consumption resulted 481,560.00 kg lowering the yearly heating specific cost to values of 14-16 $€ \cdot m^{-2}$. It was decided to consider the monthly supply of the biomasses pelleted or chipped in comparison to diesel in order to evaluate the ability of the boiler feeding system to manage fuels with different physical properties; moreover it allowed to pursue the better economic performances by choosing at the moment the most convenient product on the market.

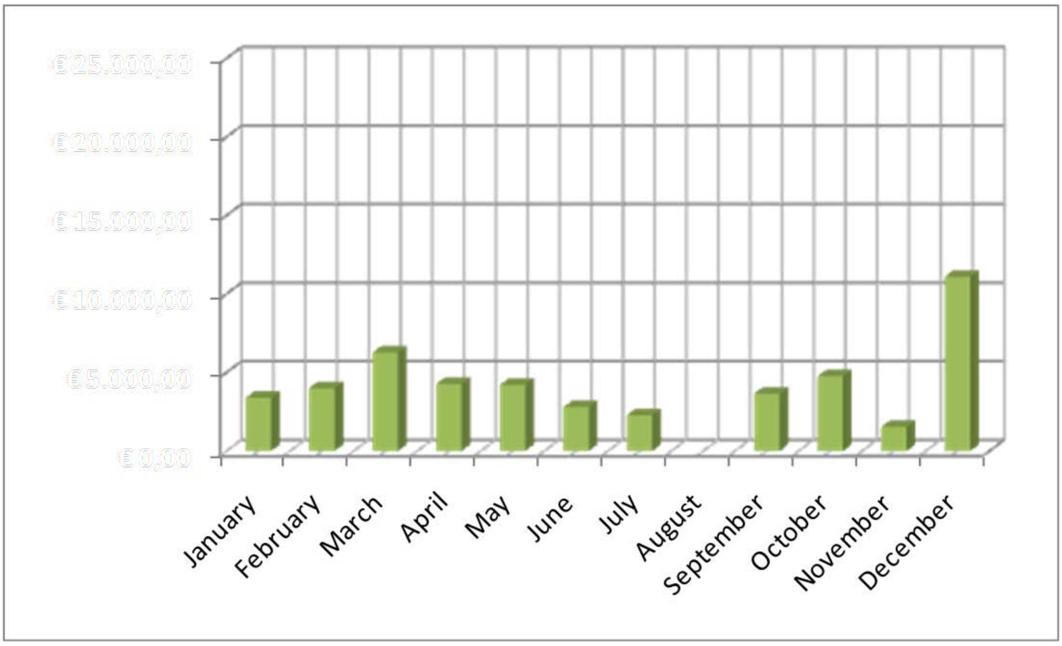

Fig. 4. Heating cost registered into the greenhouse in 2008 by biomasses.

The total fuel quantity consumed with this fuels was 3.7 times higher in weight and about 12 times in volume thus reflecting on the labour requirements and on the space needs for handling and storing the biomass.

This consequence was more evident with the wood chips gives their lower density in comparison with sawdust pellets. This was the main raison for what at the end of the considered year a gradual substitution of the chips with pellet was taken in consideration.

Other two consequences of the conversion on the general cost were an increasing of the electric power consumption due to the electric powered feeding and cleaning system of the boiler and an increasing of the labour cost for the weekly ashes removing from the boiler furnace and cyclone and the feeding auger speed adjustment following the different biomass characteristics. The most evident outcome of the conversion was a reduction of the annual cost for fuel estimated 49.9% lower in comparison with the oil standard system.

It was calculated the correlation between the values of monthly consumption of biomass and simulated values with the software Virtual Grower 2.0 and this correlation was 60%.

The differences showed between the measured and calculated data are mainly given by dissimilar weather data between the theoretical used by the software and actually recorded during the year 2008. Moreover, the differences are also attributable to the fact that actual values are related to sourcing, while the software processes the data according to the energy needs by the greenhouse depending on the weather.

Conclusions

The protected crops, cultivated in diffused Italian greenhouses, require considerable power inputs. In the case of subtropical floriculture is necessary to respect the considerable and constant needs of heat; these requirements increase and reache very high levels depending on the location of the greenhouse. In Italy, most of the greenhouses have been designed in periods during which prices for energy consumption were very low and therefore show a poor performance from an energy standpoint. Renew structures and adopt sophisticated control systems within the microenvironment is generally very expensive and also, overall, these additional investments are not always capable of increasing company revenues. Moreover, in the case of tropical and subtropical flowers, with high needs, it is not possible to find compromises between the agronomic performance of the greenhouse production system and the corresponding cost management. The replacement of the source of energy supply normally consists in diesel oil is a feasible and cost-effective solution. The decision support systems could be an useful instrument for growers to compare possible technical solutions to achieve an economic advantage and to maintain market competition.

Acknowledgements. The financial support for the national FLORENER project was provided by the Italian Ministry of agricultural, alimentary and forestry policies. The authors wish to thank Mr. Gerolamo Calleri owner of the C.&G. floricoltura, Albenga, Italy, for having made accessible the greenhouse and for the technical support.

References

Arditti, J. and Pridgeon, A.M. 1997. Orchid biology: reviews and perspectives. Vol. VII. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Blanchard, M.G., Runkle, E.S. 2005. Temperature effects on flower induction of two Phalaenopsis orchid hybrids. In: Proceedings of the 18th World Orchid Conference, Eds. A. Raynal-Roques, A. Roguenant, D. Prat. Dijon, France, p. 120-123.

Chau, J., Sowlati, T., Sokhansanj, S., Preto, F., Melin, S. and Bi, X. 2009. Techno-economic analysis of wood biomass boilers for the greenhouse industry. Appl. Energy 86(3), p. 364-371.

De Pascale, S. and Maggio, A. 2005. Sustainable protected cultivation at a Mediterranean climate. Perspectives and challenges. Acta Hort. (ISHS) 691, p.29-42

Frantz, J. 2008. Virtual Grower 2.0. USDA-ARS, Greenhouse Production Group, Toledo Ohio, USA.

Garcia, J.L., De la Plaza, S., Navas, L.M., Benavente, R.M. and Luna, L. 1998. Evaluation of the feasibility of alternative energy sources for greenhouse heating. J. of Agr. Eng. Res. 69, p.107-114.

Griesbach, R.J. 2002. Development of Phalenopsis Orchids for the mass-market. Trends in new crop and new uses. Eds. J. Janick and A. Whipkey. ASHA Press, Alexandria, VA, USA, p. 458-465.

Lee, C.S. 2002. An economic analysis of Orchid production under protected facilities in Taiwan: case of Phalenopsis. In: Proc. IS on Trop. Subtrop. Greenhouses. Eds. S. Chen and T.-T. Lin. Acta Hort. (ISHS) 578, p. 249-255.

Runkle, E.S. 2007. Innovative production systems for ornamental potted plants: a case study for Phalenopsis Orchids. In: Proc. IC on Qual. Manag. Supply Chains of Ornamentals, Eds.: S. Kanlayanarat et al., Acta Hort. (ISHS) 755, p. 55-60.

F.lo.r.ener. a Model Focuses on Energy Management for Greenhouses

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Abstract
The reduction of energy consumption is among the main goals of modern cultivation technique under greenhouse conditions. Most of the protective structures used in the European Union are aged of more than 15 years and do not always conform to current standards of low energy consumption. In most cases, the cost of investment to rebuild greenhouse plant is much more expensive for possible interventions to save energy. In many cases the old greenhouses have a high rate of air infiltration and large dispersions of heat mainly from the roof and the ventilation system. In many cases heat shields are not used and ventilation is poorly managed. To evaluate alternatives in case of new structures or to implement old structures, a decision support system (DSS) was developed to help the users in taking decisions on different possibilities both concerning the structures or the management regime. Expected results includes strategies on general maintenance to reduce energy consumption and/or to increase crop yield or energy efficiency. The software analyzes the main choices the user can take on construction, cover material, inside climate, energy sources, location. The calculations consider a stationary condition, thus the inertia is not considered. The program aims to quantify the energy demand and the relevant costs in structures defined by the user. After the elaboration - based on flowcharts - the model gives outputs as graphs with external temperature, evaporation rate, ventilation, conduction, re-irradiation, minimum temperature required. Diffuse radiation, power required, and set temperature are also showed.

Keywords: protected cultivation, energy saving, decision support tool, economic analysis.

Introduction

Reducing energy consumption is, at present, one of the major goals of technical design and implementation of greenhouses. Maintaining low energy consumption for the production of ornamental plants is necessary to have a sustainable cost of production taking into account the distribution chain in the global market. Increasing the efficiency of these structures also contributes to the reduction of greenhouse gases emission imposed by the European rules. The reduction of energetic requirements has also to reduce convective and irradiative thermal losses of structures and covering materials (Abdel-Ghany et al., 2006), increasing the efficiency of conditioning systems (Arbel et al., 2003), introducing new management practices and adopting available renewable sources of energy. Most greenhouses at present used in the EU are not designed taking into account current standards of energy efficiency as they are aged of about 15-20 years being built when the cost of energy was not a strong limit. Not always it is necessary or convenient to demolish and rebuild old greenhouses; on the contrary, simplest operations such as reducing the air infiltration rate or changing the type of fuel could decrease the heat losses or obtain lowest environmental impacts with, at the same time, better economic performance. Practically, this means a range of interventions such as replacing the covering or the heating system, introducing aluminum heat shields, a special maintenance of the greenhouse or just adjusting the set points of the heating program. Given the range of possible and alternative solutions, the availability of a Decision Support System (DSS) can provide an aid in analyzing the existing situation, i.e. asking the users to enter the required data, and presenting different scenarios comparing energy requirements and costs. The software has to take into account the Italian extremely variable climatic conditions from North to South, the age and characteristics of most of the existing greenhouses and to provide information on new investments to be implemented in order to maintain the competitiveness of the production of ornamental plants. A dynamic computer simulation model to improve greenhouses energy efficiency was developed. The program aims to quantify the energy demand and the relevant cost in the structure indicated by the user. After the elaboration based on the flowchart, the model gives outputs on graphs.

Materials and methods

The software has been developed considering three subsequent phases: i) the creation of a virtual greenhouse for analysis; it requires the use of simple data such as size, shape materials, characteristics of the heating system, geographical location and species of plants cultivated over the year thus to determine what internal conditions must be maintained in the greenhouse (Figures 1 and 2); ii) the processing of the collected data by means of the calculation model (see the description below in the detail); iii) the displaying of the results in graphical form; it provides options on the indoor climatic conditions, the energy demand of the heating system and the relevant operating costs.

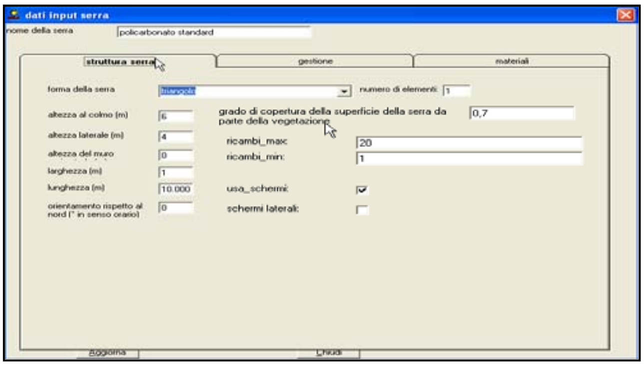

Fig. 1. An easy-to-fill mask indicates the layout of the structure to be analyzed.

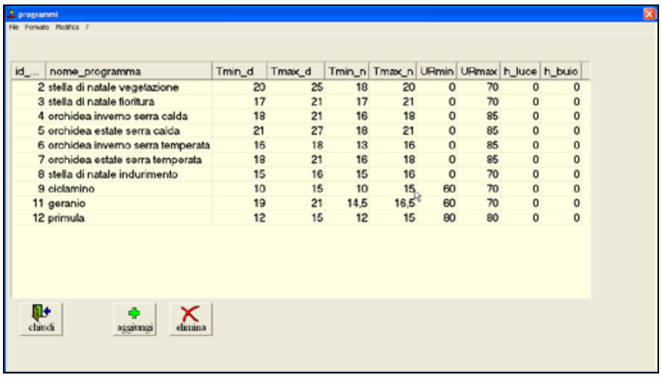

Fig. 2. A directory with the planning of most popular crops with their relevant environment requirements.

The program updates each change and can save or delete settings; it allows the user to make subsequent alterations without having to re-create another virtual greenhouse.
The calculation considers a stationary condition, thus not taking into account the inertia. The model (Figures 3 and 4) is based on the follow algorithms:
Heat gained by radiation $qi = \tau \cdot I \cdot Af$ (W)
where τ: transmittance of the cover;
I: Global radiation ($W \cdot m^{-2}$);
Af: footprint of the greenhouse on the ground (m^2);
Heat released by heating qf = net power request to the heating (W);
Heat transmitted by conduction $qc = Ai \cdot U \cdot (Ti - Te)$ (W)
where U: coefficient of heat transmission ($W^{-2} \cdot m \cdot °C^{-1}$);
Ai: area of exposed glass (m^2);
Ti: internal temperature (°C);
Te: external temperature (°C);
Heat provided by the ventilation $qv = M \cdot cp \cdot (Ti - Te)$ (W)
where M: air flow rate at $kg \cdot s^{-1}$;
cp: specific heat of air equal to 1005 $J \cdot kg^{-1} \cdot °C^{-1}$;
M value is based on flow rate required to keep the inside humidity below the required maximum value. The flow-rate is obtained by the following equation: $M = Water \cdot (Ue - Ui)^{-1}$
where M is the air flow rate in $kg \cdot s^{-1}$;
Water is the amount of evaporated water in the time unit ($kg \cdot s^{-1}$)
Ue, Ui are respectively the external and internal absolute humidity.
Water derives from the latent heat calculation (ql).
Under conditions of low or no radiation (night), the evaporated water can be calculated as a proportion of water evaporated from a free surface.
In this case, you use the following report (empirical): $g = k \cdot Af \cdot (xs-x) \cdot F \cdot r/3.6$ ($H_2O\ g \cdot s^{-1}$) where k: $(25+19 \cdot v)$;
v: air velocity inside the greenhouse ($m \cdot s^{-1}$) default to 0.2 $m \cdot s^{-1}$
F: degree of coverage of the crop in the greenhouse (decimal value);
xs: water content of air inside (instead of as a set point);
x: water content of the internal temperature of saturation;
r: coefficient reduction from empirical evaporation potential to place 0.7;
Heat lost by radiation of the greenhouse $qt = \varepsilon s \cdot \tau t \cdot \sigma \cdot Af \cdot (TKi^4 - \varepsilon a \cdot TKe^4)$ (W)
where εs: Surface emissivity (default value 0.85);
τt: thermal transmittance of the material ;
σ: constant of Stefan-Boltzman ($5.67 \cdot 10^{-8}\ W \cdot m^{-2}$);
TKI: absolute internal temperature (°K);
Ea: the air apparent emissivity (a function of dew point);
TKE: absolute external temperature (°K);
Latent heat for evapo-transpiration (taking a share of radiation) $ql = E \cdot F \cdot qi$ (W)
where E: evapo-transpiration relationship between decimal and heat by radiation;
qi: heat gained by radiation (W);
Heat balance $qi + qf = qc + qt + qv + ql$.

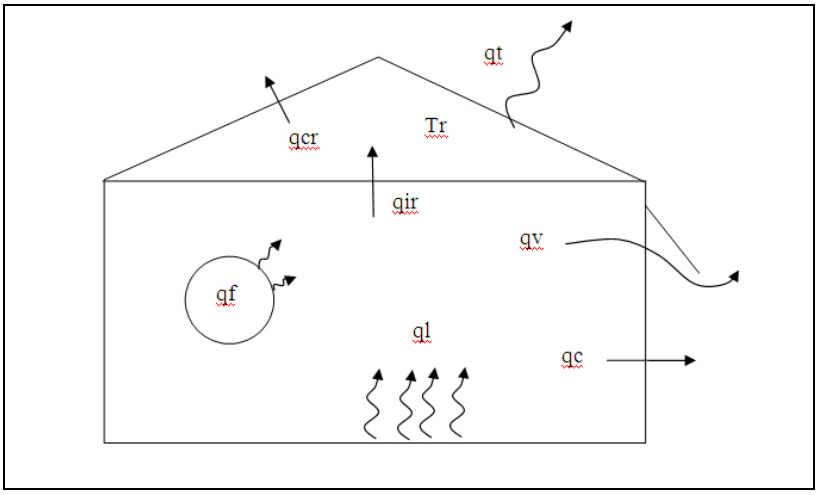

Fig. 3. Schematic outline of a greenhouse provided with heat shields.

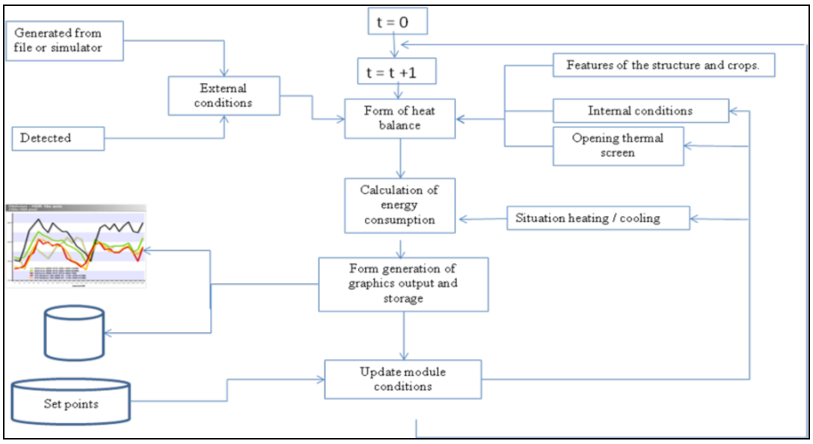

Fig. 4. Flowchart of the developed model.

If the model considers the presence of energy screens, the following two conditions have been considered: the global radiation is below 20-40 W · m^{-2} and the greenhouse requires heating. In these cases, the calculation is based on two steps: calculation of the temperature above screens (Tr) and calculation of heat requirement for maintaining the internal T value. Tr is based on the following concept: qir = qcr + qt where qir is the heat transmitted by conduction through the screen (W); qcr is the heat transmitted by conduction from the top outside (W); qt is the heat transmitted by radiation from the greenhouse (W). Once founded Tr by means of iterative calculation, the model indicates the following for the area below the screen: qf = qc + ql + qir + qv, where qc is the heat transmitted by conduction from the area under the screens to the outside (W).

The other terms are the same as those used in the calculation without screens. Therefore, ventilation is considered to be exclusively under the screens.

Results

An example of an elaborated graphic with outputs relative on external temperature, evaporation, ventilation, conduction, re-irradiation, minimum temperature required is provided in Fig. 5. Diffuse radiation, power required, and set temperature are showed in Figure 6. The data derives from calculation based on a specific greenhouse design which characteristics have been introduced in the software by the user. The software gives the possibility to vary the structure layout or the management strategy in order to put the user in condition to compare alternative solutions. One of the most important source of variability of the model derives from the year-to-year variability in weather conditions. In this case, the considered database on local climatic conditions was obtained by averaging, over ten years, the hourly values of the parameters taken into consideration such as air temperature and humidity and solar radiation.

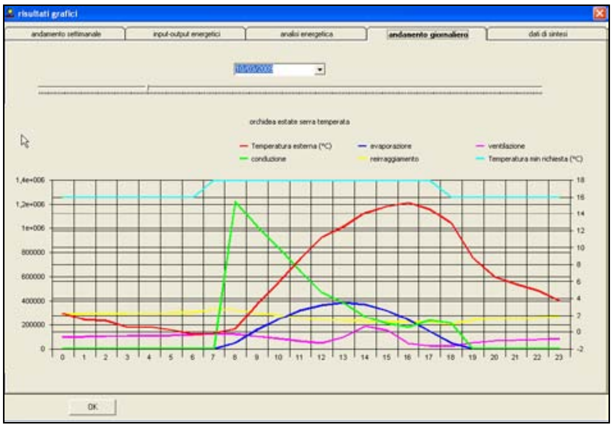

Fig. 5. Example of output provided by the model: external temperature, evaporation, ventilation, conduction, re-irradiation, minimum temperature required.

Fig. 6. Outputs by the model: external temperature, power required, set temperature, diffuse radiation.

At the present development of the software, one year of real data campaign collected by commercial greenhouses has been completed; the data will be used to validate the model in order to assess the software performance in providing solid correspondences between real and simulated conditions.

Conclusions

A Decision Support System to evaluate the energy requirements and the relevant cost in greenhouses for ornamental plants production has been developed. The program can be used as a guideline for improving energy efficiency by simulation of virtual greenhouses. The system has a potential to be widely used among greenhouse growers and manufacturers. For a better applicability, other modules need to be added such as water consumption, manpower need and crop quality.
Recommendations are given to the users in order to perform simulations with the real and intended characteristics of their greenhouse in order to evaluate the economic feasibility of improvements.

Acknowledgements

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References

Abdel-Ghany, A.M., Istigami, Y., Goto, E. and Kozai, T. 2006. A method for measuring greenhouse cover temperature using a thermocouple. Biosystems Eng. 95(1):99-109.

Arbel, A., Barak, M. and Shklyar, A. 2003. Combination of forced ventilation and fogging systems for cooling greenhouses. Biosystems Eng. 84(1):45-55.

Bakker, J.C., Boulard, T., Adams, S.R., Montero, J.I. 2007. Innovative Technologies for an Efficient Use of Energy. Proc. IS on Greensys2007. Acta Hort. 801: 49-62.

Beshada, E., Zhang, Q. and Boris R. 2006. Winter performance of a solar energy greenhouse in southern Manitoba. Canadian Biosystems Eng. 48:5.1-5.8.

Djevic, M., Dimitrijevic A. 2007. Energy Consumption for Different Greenhouse Constructions. Proc. IS on Greensys2007. Acta Hort. 801: 781-786.

Dougherty, B.P., Fanney, A.H. and Davis, M.W. 2005. Measured performance of building integrated photovoltaic panels. J. of Solar Energy Engineering 127:314-323.

Elings, A., Kempkes, F.L.K., Kaarsemaker, R.C., Ruijs, M.N.A., van de Braak N.J., Dueck, T.A. 2005. The Energy Balance and Energy-Saving Measures in Greenhouse Tomato Cultivation. Proc. IS on Greensys, Acta Hort. 691, 67-74.

Griffiths, F.J. 1994. Handbook of agricultural meteorology. Oxford University Press, Inc., New York Oxford, p. 320.

Korner, O., Bakker, M.J., Heuvelink E. 2004. Daily Temperature Integration: a Simulation Study to quantify Energy Consumption. Biosystems Eng. 87(3):333-343.

Korner, O., Eveleens, B., Heuvelink E., Warner, D., Tzilivakis, J. 2007. Decision Support for Optimising Energy Consumption in European Greenhouses. Proc. IS on Greensys 2007. Acta Hort. 801: 803-810.

Kumari, N., Tiwari, G.N. and Sodha, M.S. 2007. Performance evaluation of greenhouse having passive or active heating in different climatic zones of India. Agri. Eng. Intl. The CIGR Ejournal. Manuscript EE 06 011. Vol. IX.

Lopez-Cruz, I.L., Ramirez-Arias A., Rojano-Aguilar A. and Ruiz-Garcia A. 2007. Modeling of Greenhouse Climate Using Evolutionary Algorithms. Proc. IS on Greensys 2007. Acta Hort. 801: 401-408.

Tijskens, L.M.M. and Vollebregt, H.M. 2003. Supply chains in new and emerging fruit industries: the management of quality as a strategic tool. Acta Hort. 604:75.

Van Henten, E.J., Bakker, J.C., Marcelis, L.F.M., van't OOster, A., Dekker, E., Stanghellini C., Vanthoor, B., Van Randeraat B. and Westra J. 2006. The Adaptative Greenhouse – an Integrated Systems Approach to Developing Protected Cultivation Systems. Proc. III on HORTIMODEL 2006. Acta Hort. 718, 399-406.

Yildiz, I., Stombaugh, D.P. 2007. Simulated Effect of Various Environmental Management Practies on Energy Consumption in Open and Confined Greenhouse Systems. Proc. IS on Greensys 2007. Acta Hort. 801: 1317-1324.

A Simulation Model for the Exploitation of Geothermal Energy for a Greenhouse in the Viterbo Province

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Abstract

The increasing demand of energy for industrial production and urban facilities asks for new strategies for energy sources .

In recent years an important problem is to have some energy storage, production and consumption which fulfill in some environment friendly expectations. Much more attention has been recently devoted to renewable energies.

Among them energy production from geothermal sources has becoming one of the most attracting topics for engineering applications. Ground coupled heat transfer might give an efficient energy for well-built construction.

At a few meters below the earth's surface the underground maintains a constant temperature in a approximation through the year allowing to withdraw heat in winter to warm up the habitat and to surrender heat during summer to refresh it.

Exploiting this principle, heat exchange is carried out with heat pumps compound to vertical ground heat exchanger tubes that allows the heating and cooling of the buildings utilising a single plant installation. This procedure ensure a high degree of productivity, with a moderate electric power requirement compared to performances.

The aim of this work is the simulation with the TRNSYS program of the geothermal plant needed for air conditioning a greenhouse in Viterbo. The model realized has allowed to set up the plant for the heat exchange with the thermal basin, defining the technical elements and verifying the exploitation of geothermal system in a greenhouse in the outskirts of Viterbo.

Keywords: heat exchange, TRNSYS, heat pumps

Introduction

Geothermal (ground-source) heat pumps (GHP) are one of the fastest growing applications of renewable energy in the world, with annual increases of 10% in about 30 countries over the past 10 years (Lund, Sanner, Rybach, Curtis, Hellström, 2004). In Europe, like some other southern countries, Italy has been one of the last countries to find interest in ground source heat pumps; the reasons should probably be found in some aspects:

– mild climate, because of the Mediterranean closed sea, with minimum temperatures normally not less than -3°C and maximum temperature not more than 30-35°C;

– different approaches to the heating solutions; in Italy there is a habit to natural gas furnaces, because there is a huge pipe network, that supply the gas at low cost, nearly to everyone; only isolated villages or houses in the countryside, isles, hills or mountains, are not reached by the gas net and they usually adopt propane gas or oil, as fuels for furnaces;

– a general culture that erroneously identifies electricity for heating with electric resistance, with an immediate callback to high running costs;

– low interest in renewable energies. Geotherm srl Earth Energy Systems was founded in the year 2000 after some years of groundwork and planning. The inspiration for the firm arrived by chance from a short article with the description of heating and cooling systems in the USA, that were "plugged to earth" (Maritan and Panizzolo, 2008).

Today, the Italian geothermal heat pumps market is still a niche one, where people show good interest but where different technical approaches, competitors and designers introduce a quite wide number of solutions, plugged to the ground: these solutions are sometimes standard and well tested, sometimes not tested or well designed; the effect is that the number of not working systems or saturated ground loops are growing too, with bad influence to the entire market. The second effect is that the final ground source customer is now often confused because he/she is pushed by companies or thermal engineers to follow a way and the opposite of it.

The use of greenhouses for growing plants is widely used in Italy. The design and implementation of greenhouses is done without the study of energy exchanges between the external environment inside the greenhouse. Climatic conditions are evaluated only on the plant species planted without verifying the construction parameters of the greenhouse or efficiency of air conditioning systems.

Greenhouses are the primary use of geothermal energy in the agribusiness industry. Most greenhouse operators estimate that using geothermal resources instead of traditional energy sources saves about 80% of fuel costs — about 5% to 8% of total operating costs. The relatively rural location of most geothermal resources also offers advantages, including clean air, few disease problems, clean water, a stable workforce, and, often, low taxes. This paper verifies the efficiency geothermal plan with TRNSYS 16.

Materials and methods

Geothermal heating and cooling

Geothermal heating and cooling systems provide space conditioning, heating, cooling, and humidity control. They may also provide water heating , either to supplement or replace conventional water heaters. Geothermal heating and cooling systems work by moving heat, rather than by converting chemical energy to heat like in a furnace. Every geothermal heating and cooling systems has three major subsystems or parts: a geothermal heat pump to move heat between the building and the fluid in the earth connection, an earth connection for transferring heat between its fluid and the earth, and a distribution subsystem for delivering heating or cooling to the greenhouses.

The geothermal heat pump is packaged in a single cabinet, and includes the compressor, loop-to-refrigerant heat exchanger, and controls. Systems that distribute heat using ducted air also contain the air handler, duct fan, filter, refrigerant-to-air heat exchanger, and condensate removal system for air conditioning. For home installations, the geothermal heat pump cabinet is usually located in a basement, attic, or closet. In commercial installations, it may be hung above a suspended ceiling or installed as a self-contained console.

Most greenhouses geothermal systems use conventional ductwork to distribute hot or cold air and to provide humidity control (a few systems use water-to-water heat pumps with one or more fan-coil units, baseboard radiators, or under-floor circulating pipes). Properly sized, constructed, and sealed ducts are essential to maintain system efficiency. Ducts must be well insulated and, whenever possible, located inside of the building's thermal envelope (conditioned space). Geothermal heating and cooling systems for large commercial buildings, such as schools and offices, often use a different arrangement. Multiple heat pumps (perhaps one for each classroom or office) are attached to the same earth connection by a loop inside the building. In this way, each area of the building can be individually controlled. The heat pumps on the sunny side of the building may provide cooling while those on the shady side are providing heat. This arrangement is very economical, as heat is merely being transferred from one area of the building to another, with the earth connection serving as the heat source or heat sink only for the difference between the building's heating and cooling needs.

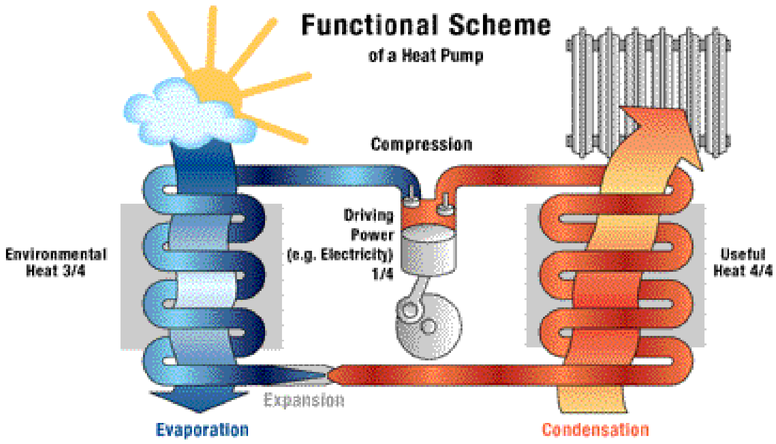

Figure 1. Heat pump scheme

The key to the efficiency of a GSHP is the Coefficient of Performance: the "C.O.P.". In spite of the first law of thermodynamics, which tells us that energy can neither be created nor destroyed, a GSHP in a good installation can yield up to four units of heat for each unit of electricity consumed. Naturally the heat pump is not creating this energy, but merely separating a medium temperature from the ground into warmth (which can be used for heating) and cold (which can be returned to the ground). The C.O.P. will vary with each installation, but the lower is the output temperature to the heat distribution system the higher the C.O.P. will be. If an output temperature of 60°C is needed to heat radiators the C.O.P. is likely to fall to level of only 2.5. If the heat distribution is to a well designed underfloor heating system that works well at an output temperature of 40°C then the C.O.P. can rise to a level of 4. The input temperature is also critical to the C.O.P. of the heat pump. The higher the input temperature from the ground, the lower the amount of work needed from the heat pump, the higher the C.O.P. will be. In fact, the critical factor is the "uplift" between the source temperature and the output temperature. Normally a GSHP starts with a ground temperature of about 10°C: this is the natural temperature of the ground at a depth of six metres. This temperature of around 10°C will be found across Great Britain, summer or winter, unless unusual conditions apply. The reason is that heat only moves very slowly in the ground. Unusual conditions will be found where a heat pump is in action: as a heat pump draws heat from the ground the ground temperature will fall from the natural level of 10°C to a lower level (which depends on the amount of heat drawn from the ground and the volume of ground from which it is extracted). As the ground temperature gets colder the heat pump will have more work to do to deliver the output temperature required for heating. In these conditions the C.O.P. of the heat pump will fall below the rule of thumb figure, often given, of 4. If asked to extract heat from ground which is too cold, the ground source heat pump will "Lock Up". Normally a GSHP starts with a ground temperature of about 10°C: this is the natural temperature of the ground at a depth of six metres. This temperature of around 10°C will be found across Great Britain, summer or winter, unless unusual conditions apply. The reason is that heat only moves very slowly in the ground. Unusual conditions will be found where a heat pump is in action: as a heat pump draws heat from the ground the ground temperature will fall from the natural level of 10°C to a lower level (which depends on the amount of heat drawn from the ground and the volume of ground from which it is extracted). As the ground temperature gets colder the heat pump will have more work to do to deliver the output temperature required for heating. In these conditions the COP of the heat pump will fall below the rule of thumb figure, often given, of 4. If asked to extract heat from ground which is too cold, the ground source heat pump will "lock up".The C.O.P. is critical because, although a heat pump can be efficient, electricity is more expensive than gas. If we do not get a high C.O.P. from the heat pump it could be cheaper to use a gas boiler for heating. In terms of carbon saving a heat pump releases no CO_2 on site, but you should consider the CO_2 emitted at the power stations to create the electricity to use.

Geothermal Greenhouse model with TRNSYS

The TRNSYS is a software commonly used to simulate transient heat transfer for the design and control of power systems using renewable energy sources. Another frequent use of the software is now on the energy certification for homes, offices, shops, restaurants and industries. In this sense the present work is an example of using the software for agricultural systems. The greenhouse considered is a steel structure prefabricated construction, used for growing flowers and plants and with glass cover.

The outline of the project is as follows:

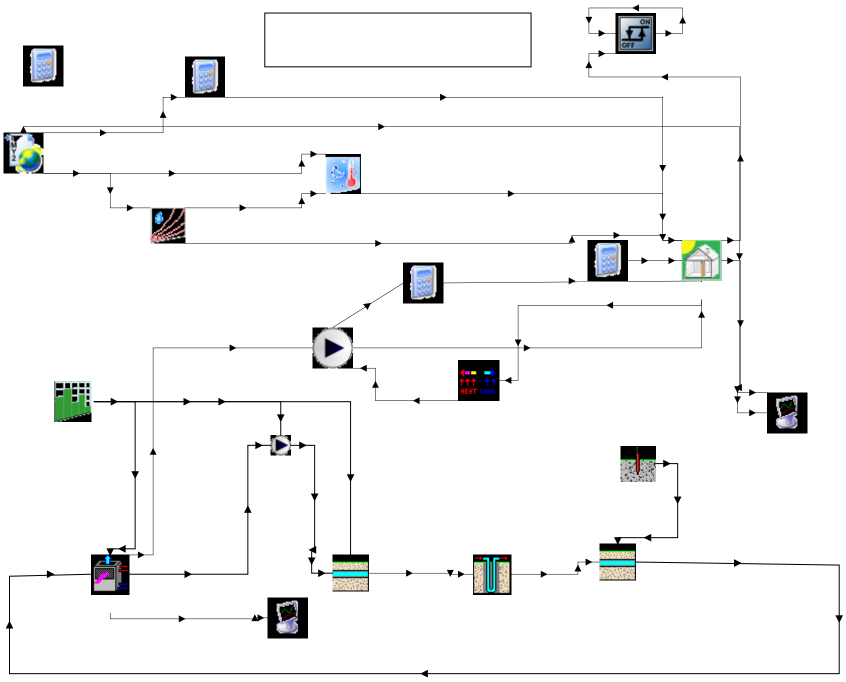

Figure 2. Geothermal greenhouses project

Where icons mean:
- Turn: building orientation converter
- Weather data: weather data reader
- Radiation: solar radiation converter for surfaces

- Psychrometrics: psychrometrics computer
- Sky temp.: CPU Sky Temperature
- Nat. Vent.1: natural ventilation controller
- Building: Greenhouse (Type 56)
- Cooling: cooling temperature set
- Temp. Control: heating and cooling controller (on/off)
- Airchanges: heating and cooling airchanges computer
- Pump, Pump-2: conditioning pump and geothermal system pump
- Heat Pump: heat pump
- On/off Function: geothermal system controller (on/off)
- Soil Temperature: soil thermal probe
- Pipe, Pipe-2, Pipe-3: geothermal system pipes and heat exchangers
- Temperature: temperature charts creator
- C.O.P.: C.O.P. charts creator.

The approach of the model was carried out by using the program TRNSYS Simulation Studio. It was done starting with the path led to the construction of a multizone building, which is divided into multiple steps where the user enters the data of the building and its location in space. The data required by the software at this stage will be used for the automatic construction of the project and its connections between the components. For setting-up the project there is also the source of meteorological data that will be used in the simulation. This is indeed a link with the Type 109 (Weather Data Processor) selected from the meteorological station of Viterbo. As for the greenhouse, we have chosen the climate system geothermal, with radiant ground.

Mathematical description of the geothermal model

In this section is described in detail the matematical modelling of the geothermal plant. It will be also shown how they can be regulate by the user, who must fit single components by connecting all the time-dependent variables, and describing fixed parameters.

Ground temperature profile

This model calculate the vertical temperature distribution of the ground given the mean ground surface temperature for the year, the amplitude of the ground surface temperature for the year, the time difference between the beginning of the calendar year and the occurrence of the minimum surface temperature, and the thermal diffusivity of the soil. These values may be found in a variety of sources including the ASHRAE Handbooks (refer to soil temperature).

Kasuda found that the temperature of the undisturbed ground is a function of the time of year and the depth below the surface and could be described by the following correlation:

$$T = T_{mean} - T_{amp} * \exp\left[-depth * \left(\frac{\pi\alpha}{365}\right)^{0.5}\right] * \cos\left\{\frac{2\pi}{365} * \left[t_{now} - t_{shift} - \frac{depth}{2} * \left(\frac{365\alpha}{\pi}\right)^{0.5}\right]\right\}$$

Where:

T [°C]	Temperature
Tmean [°C]	Mean surface temperature (average air temperature)
Tamp [°C]	Amplitude of surface temperature
Depth [m]	Depth below surface

α [m^2/hr] Thermal diffusivity of the ground (soil)
tnow [1..365] Current day of the year
tshift [1..365] Day of the year corresponding to the minimum surface temperature

Water source heat pump

This component models a single-stage liquid source heat pump with an optional desuperheater for hot water heating. The heat pump conditions a moist air stream by rejecting energy to (cooling mode) or absorbing energy from (heating mode) a liquid stream. This heat pump model was intended for a residential ground source heat pump application, but may be used in any liquid source application. The heat pump has a desuperheater attached to a secondary fluid stream. In cooling mode, the desuperheater relieves the liquid stream of some of the burden of rejecting energy. However, in heating mode, the desuperheater requires the liquid stream to absorb more energy than is just required for space heating.

This model is based on user-supplied data files containing catalog data for the capacity (both total and sensible in cooling mode), and power, based on the entering water temperature to the heat pump, the entering water flow rate and the air flow rate. Other curve fits are used to modify the capacities and power based on/off design indoor air temperatures. This model takes either air relative humidity or absolute humidity ratio as an input. A scheme of the model is shown in Figure 3.

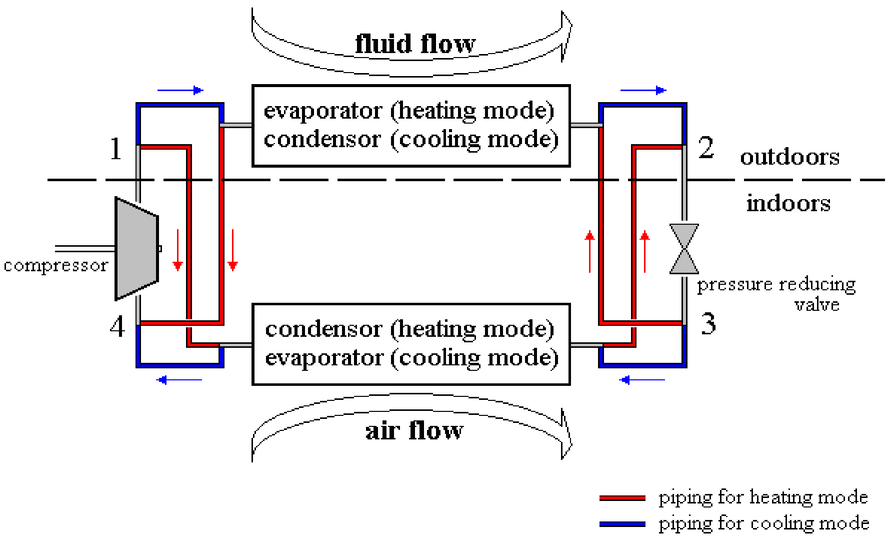

Figure 3. Heat pomp scheme in TRNSYS.

Detailed buried pipe

The pipe component models a horizontal ground coupled heat exchanger or, more simply, a horizontal pipe buried in the earth. This model accounts for ground seasonal temperature variations and backfilling of the trench containing the pipe. The fluid convection, the pipe wall, and the backfilled material are all represented as a net resistance. The inner soil nodes, those in contact with the backfill are also modeled without capacitance.

The rest of the nodes within the soil are modeled as capacitors connected by resistors in both the radial and circumferential directions.

Vertical ground heat exchangers

This is a model for a vertical heat exchanger that interacts thermally with the ground. This ground heat exchanger model is most commonly used in ground source heat pump applications. This subroutine models either a U-tube ground heat exchanger or a concentric tube ground heat exchanger. A heat carrier fluid is circulated through the ground heat exchanger and either rejects heat to, or absorbs heat from the ground depending on the temperatures of the heat carrier fluid and the ground. In typical U-tube ground heat exchanger applications, a vertical borehole is drilled into the ground. A U-tube heat exchanger is then pushed into the borehole. The top of the ground heat exchanger is typically several feet below the surface of the ground. Finally, the borehole is filled with a fill material; either virgin soil or a grout of some type. In typical concentric tube heat exchanger application, the borehole is just slightly larger than the outer pipe of the ground heat exchanger, but the same process applies. The borehole is drilled into the ground, and the heat exchanger is pushed into the borehole.

Figure 4 shows one U-tube per borehole; although this subroutine allows the user to have up to 10 U-tubes per borehole.

The program assumes that the boreholes are placed uniformly within a cylindrical storage volume of ground. There is convective heat transfer within the pipes, and conductive heat transfer to the storage volume. The temperature in the ground is calculated from three parts; a global temperature, a local solution, and a steady-flux solution. The global and local problems are solved with the use of an explicit finite difference method. The steady flux solution is obtained analytically. The temperature is then calculated using superposition methods.

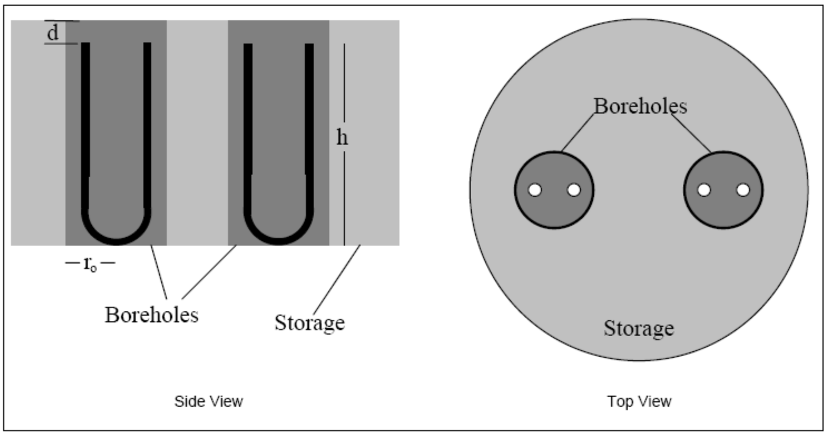

Figure 4. Side view and top view of a U-tube.

Results

The purpose of the simulation is to check the temperatures inside the greenhouse related to external climatic parameters and the type of construction of the greenhouse itself. The required energy for optimal climate conditioning is based on such calculation. These values in fact are calculated in order to maintain an optimal temperature of 20 °C which is considered suitable for the cultivation of a wide range of plant species.

The graph in Figure 5 shows the trend of annual temperatures inside and outside the greenhouse. As it can be saw, the internal temperature, represented by the red line, remains in the required range (15-24 °C) and the outside temperature, represented by the blue line, is lower in winter months (marginal parts of the graph) and higher in warmer months (middle graph). This means that geothermal air conditioning is well dimensioned, so it can provide the energy demand in the greenhouse, ensuring the ideal thermal regime for the nurse.

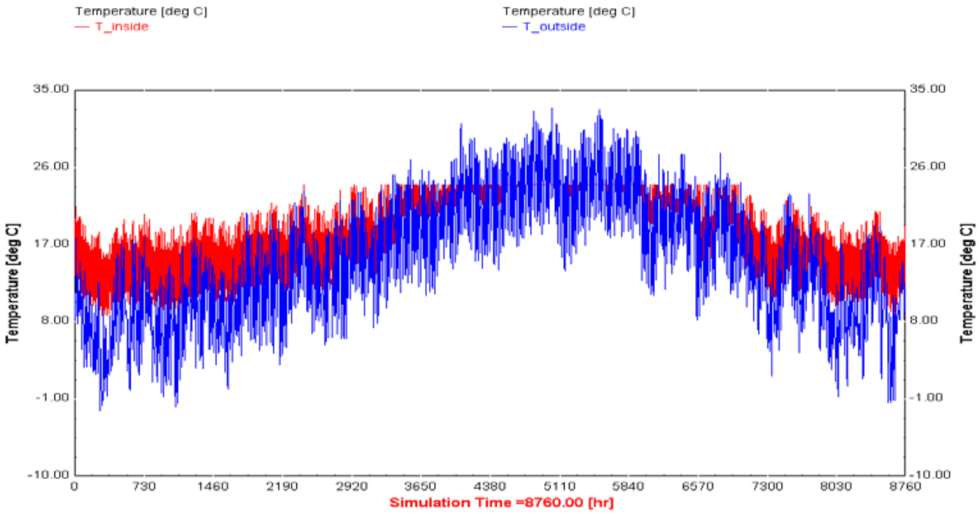

Figure 5. Inside and outside temperature annual simulation results.

After observing the evolution of temperature, it is interesting to see the 'efficiency' of the conditioning system by evaluating the efficiency of geothermal heat pump. The yield of a heat pump is measured by the Coefficient Of Performance, C.O.P., defined as the ratio between energy output (at the source of interest) and energy consumed (usually electricity). A value of the CO.P., for example 3, indicates that for every kWh of electricity consumed, the heat pump will make 3 kWh of heat. The graph in Figure 6 shows the annual pattern of C.O.P. heat pump chosen for this project, represented by the red line. As you can see the value of C.O.P. stays between 5.3 and 5.7. during the year. This can be considered an excellent result and well above common values, probably due to the simplicity of the system.

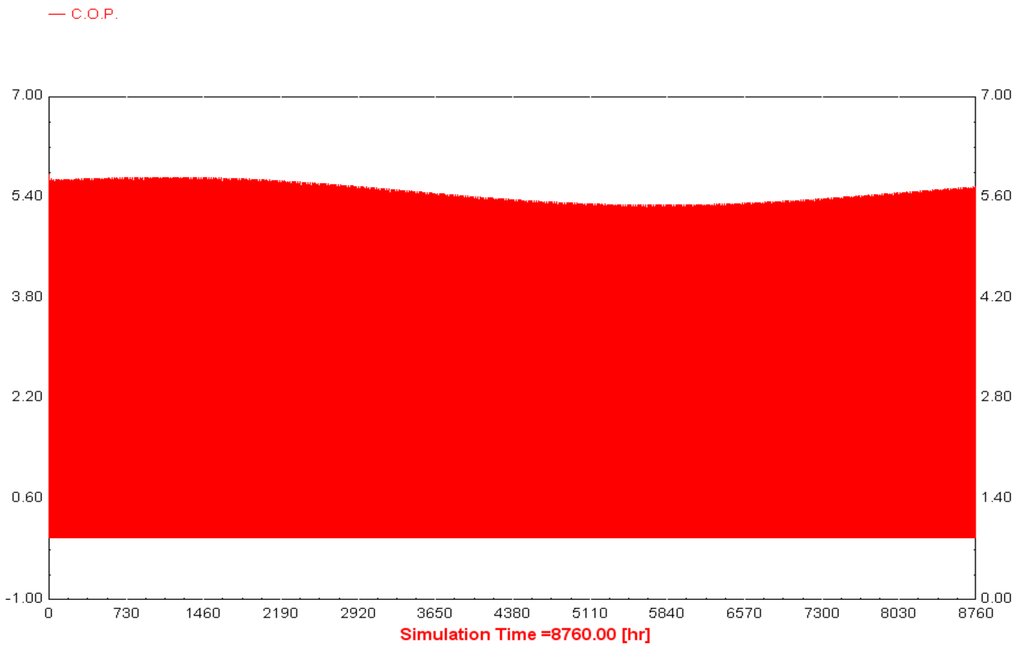

Figure 6. Coefficient Of Performance (C.O.P.) annual simulation

Once defined this optimal situation we could have results of every time-dependent variable choice from TRNSYS. For example we can know how much heat we have to put in or remove from the system for having those inside temperatures during the year, or how many electric energy we must give to the heat pump.

Conclusions

TRNSYS software has demonstrated an extreme flexibility to allow development of the project emissions. The construction of the model has been simplified by the procedures explained in a comprehensive manner in the various manuals provided with the software, without showing any particular difficulties in communications between the constituent subprograms.

From this model, it might be interesting to continue to work on projects for energy systems applied to agriculture, being able to predict the indoor climatic conditions and from this starting to figure out which crops are actually achievable.

In addition, this program offers many opportunities of improvement: could be inserted everything else necessary to simulate the best situations in the various case studies, building easily new components (Types) on variables purely "agricultural", as the plant transpiration and soil evaporation, soil temperature and soil heat exchange, crops growth and any other time-dependent variable.

References

1. Kasuda, T., Archenbach, P.R. 1965, Earth temperature and thermal diffusivity at selected stations in the United States. ASHRAE Transactions, Vol. 71, Part 1.

2. Maritan D., Panizzolo R., 2008, Ground source heat pumps applications in Italy proceedings. Thirty-third workshop on geothermal reservoir engineering, Stanford University, Stanford, California, January 28-30, 2008 sgp-tr-185.

3. Martin M., Berdahl P., 1984, Characteristics of infrared sky radiation in the United States. Solar Energy Vol. 33, No. 3/4, pp. 321-336.

4. Mitchell J.W., Braun J.E., 1997, Design Analysis, and Control of Space Conditioning Equipment and Systems. Solar Energy Laboratory, University of Wisconsin – Madison.

5. Perez R., Stewart R., Seals R., Guertin T., 1988, The development and verification of the Perez diffuse radiation model. Sandia Report SAND88-7030, 1988.

6. Randall C.M., Whitson M.E., l977, Hourly insolation and meteorological data bases including improved direct insolation estimates. Aerospace Report No. ATR-78 (7592)- l.

7. Reindl D. T., Beckman W. A., Duffie J. A., 1990, Diffuse fraction correlations. Solar Energy, Vol. 45, No. 1, pp. 1-7.

8. Reindl D. T., Beckman W. A., Duffie J. A., 1990, Evaluation of hourly tilted surface radiation models. Solar Energy, Vol. 45, No. 1, pp. 9-17.

Climate Conditions in a Livestock Building in Molise: Experimental and Numerical Analysis

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Abstract

Climate control in livestock buildings has a key influence on the productivity and health but it is also a difficult and complex task as the bred animals considerably affects temperature and humidity conditions inside the cowshed.

Inaccurate knowledge of the ventilation rates is the major cause of production losses and ventilation-related health problems in modern cattle breeding.

Main aim of the present research was the study of the influence of the forced and natural air ventilation on mixing performance in a livestock located in Molise-Italy. Climate conditions were evaluated by mean of temperature distribution in space and time and carbon dioxide in two given points in the livestock building.

Keywords: livestock, ventilation, control

Introduction

Climate control in livestock buildings is very important for farm productivity and animal health but it is difficult and complex to know how much do the bred animals affect the temperature and the humidity inside the cowshed. Currently in Italy there are still many areas where the breeding takes part in family managed structures and with a limited number of animals. It is exactly in these productive environments that the control of micro-climatic aspects of the shelters is necessary to guarantee a healthy environment for the animals and for the employees.

Ventilation and temperature control in the livestock buildings is usually attained by applying the conventional staged ventilation systems to keep the internal environment according to desired conditions; anyway the livestock farmer may not be able to satisfy the various requirements for cattle products or to meet increasingly stringent regulations on farming methods to decrease the environmental impact or provide a higher standard of animal welfare.

Inaccurate knowledge of the ventilation rates is a major cause of production losses and ventilation-related health problems in modern cattle breeding.

The goal of the present research was a study on the effect of the forced and natural air ventilation in a livestock located in Molise-Italy.

Materials and Methods

Climate conditions were evaluated by means of temperature distribution in space and time and carbon dioxide concentration in two given points in a livestock building in Molise (Italy). The farm is located in Sepino (CB) and was built in the 80's Years. The used housing is the stall one with short seat and with a head to head disposition. The shelter is connected to service and deposit structures. The refuge has an area of 260 m^2, the external walls has been

realized by cement face bricks with 2 air spaces. The roof is made by two undulated cement asbestos boards with a glass wool sheets cavity, and it is supported by purlins and iron beams. The group was composed by 12 cows (average weight 600Kg/head) and 18 calves (average weight 325kg/head).
Measurements were performed using a multi-channels data logger equipped with resistance temperature sensors for its distribution in a half side of the whole space of the tested livestock building and two temperature-CO_2 sensors located in the centre and in a low air-mixing zone of the building.
The micro-climatic analysis inside the breeding has been developed by mean of a data acquisition and processing system during a three months period. For temperature acquisition the Lastem Babuc ABC was used equipped with 24 thermo-resistors located in 8 horizontal positions and vertically arranged in groups of three (Fig. 1). Moreover Onset Hobo located in two other points and equipped with the Telaire CO_2 detector were used to acquire both temperature and carbon dioxide concentration
We have detected the data during:

- forced and natural ventilation since 05/11/2009 to 11/11/2009;
- natural ventilation since 31/12/2009 to 07/01/2010;
- natural ventilation with translated Hobo since 21/01/2010 to 29/01/2010.

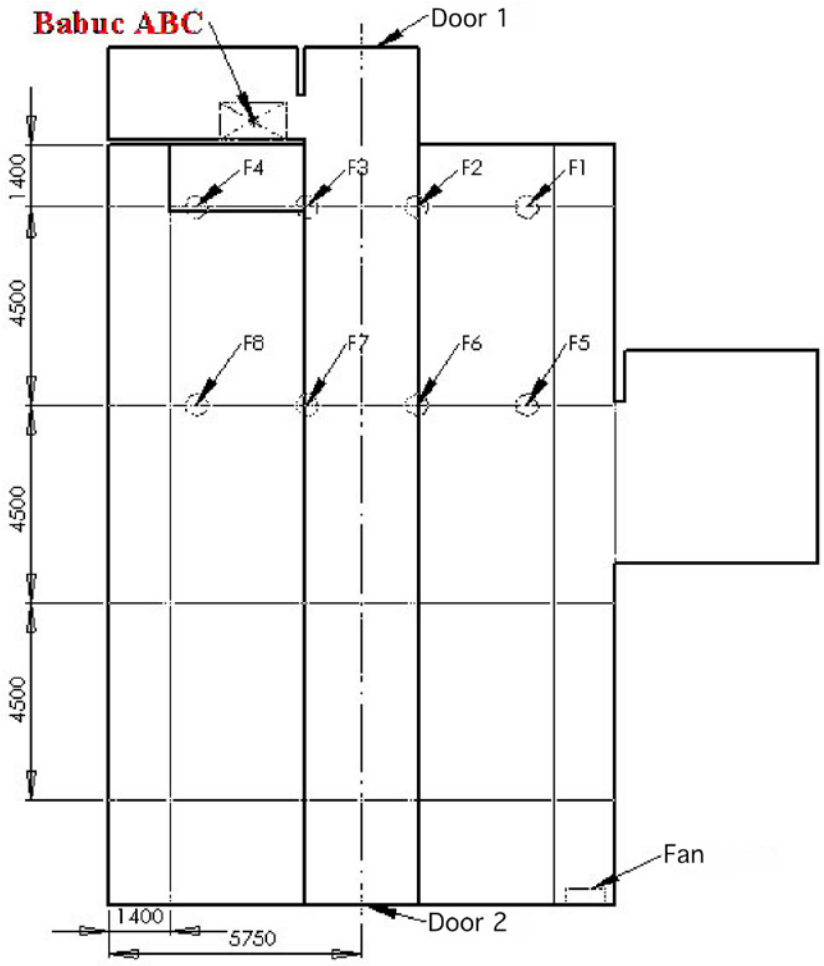

Figure 1. Shelter plan with temperature sensor and CO_2 detector locations.

Results

Measurement results are showed in terms of a temperature distribution graph (Fig. 2) in different ventilation conditions pointing out space-time variations. These data are then related to CO_2 measurements in order to highlight not so good air mixing and renewing affecting wellness of animals housed inside.

The forced ventilation system was automatically activated if the temperature went under the 22°C. The temperature was detected by a thermostat located near the central Hobo. The higher early-morning temperature is due to the closed doors during night time that don't allow the air change in the breeding, while the minimum temperature is due to the opened doors for the foods load and unloading.

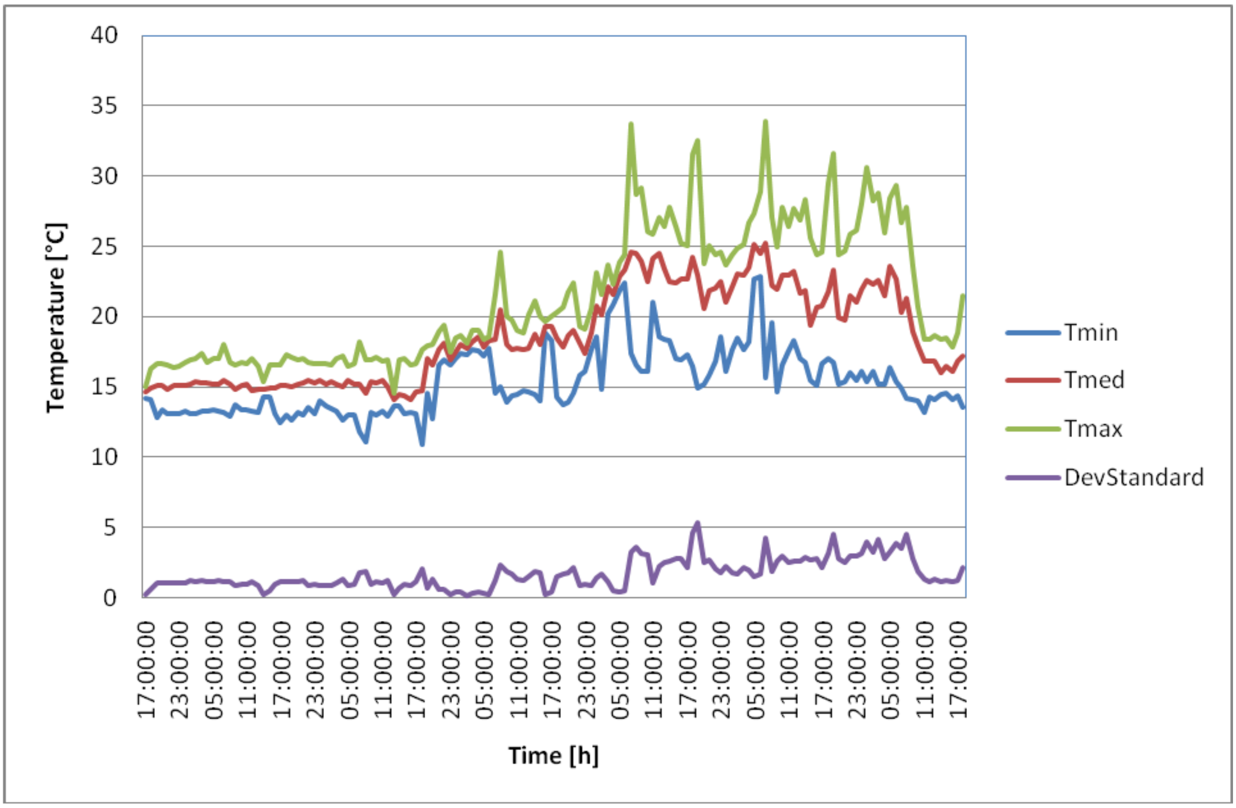

Figure 2. Temperature in position F7.

Figure 2 shows the temperature inside the breeding detected by the data logger Babuc in position F7: sampling time was 1s and minimum, mean and maximum values are calculated during one minute and over the group of three thermo-resistors for each plotted value. During the first three days an almost constant temperature can be observed as forced ventilation was used, then very large variations occur as the ventilation system was stopped due to technical problems in fan equipments.

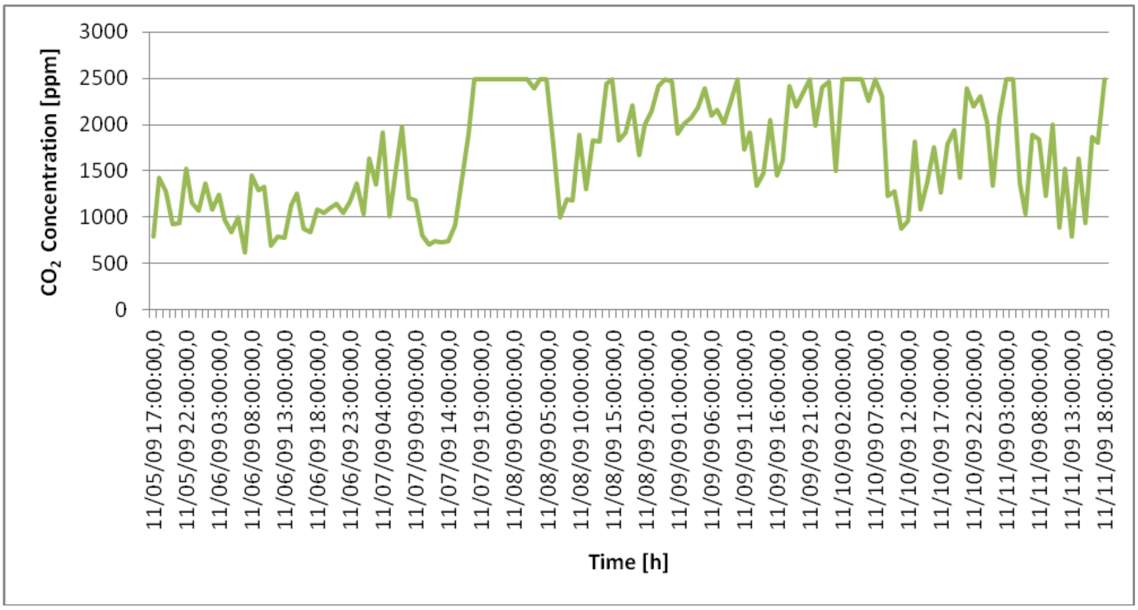

Figure 3. Carbon dioxide concentrations (Lateral position).

Fig. 3 shows the carbon dioxide concentration trend. It is clear that during the forced ventilation period (first three days), the values never exceed 2485 ppm which is the storing limit of the Onset Hobo.
Greatest values (2485 ppm) can be observed after milking (20:00) and in the first hours of the morning (7:00) and in both cases only during the turning off fan period. This could even mean that the maximum level allowed for animals health is likely to be exceeded in these conditions

Conclusions

The work carried out give us the possibility to get information related to the trend of some parameters helping to determinate the assess of animals breeding conditions. By the analysis of environmental parameters is possible to assert that with forced ventilation, during the autumn, the variability of inside temperatures is very low and their stratification in plant is homogeneous.
At the opposite during the natural ventilation, in the autumn season, the inside temperature is higher with differences of over 5°C.
These data could be also useful to add more information on animal welfare and beef traceability. Continuous monitoring of micro-environmental parameters could be a tool used by the breeders to improve cowshed management.

References

CGIR Report Climatization of Animal Houses Report of Working group. 1984. Scottish Farm Building Investigation Unit. Craibstone, Aberdeen, Scotland.

Mader T. et al. 2000. Managing feedlot heat stress. Published by University of Nebraska, Lincoln Extension, Institute of Agriculture and Natural Resources.

Müller H.J., Rom H.B., Pedersen S. 2006. Comparison of Methods of Determination of Ventilation Flow in Animal Houses with Different Kinds of Animals. Proceedings of XVI CIGR World Congress – Agricultural Engineering for a Better World, Bonn (Germany), 3-7 September 2006. CDROM printed.

Pedersen S., Sallvik K. 1992. CGIR 2nd Report of Working Group on Climatization of Animal Houses.

Pedersen S., Sallvik K. 2002. CGIR 4th Report of Working Group on Climatization of Animal Houses. Heat and moisture production at animal and house levels.

Simoni A, Giametta F., La Fianza G. 2008. A method of control for the ventilation and recording of: temperature, relative humidity and light in beef traceability. The Open Agriculture Journal, – *Bentham OPEN*, 2, 49-53

St-Pierre N. R. et al. 2003. Economic losses from heat stress by US livestock industries. Journal Dairy Science - Vol. 86 - E52/E77.

The Biomasses Deriving From the Public Parks Management: an Hypothesis of a City-Wood-Energy Chain in Potenza

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Abstract

The aim of this work was to hypothesize a city-wood-energy chain in Potenza, using the residuals deriving from the public parks maintenance.
In this study it emerged a maintenance conditioned from the scant municipal funds and the assimilation of the wood residuals to a common urban waste. From here was originated the hypothesis of a chain, to exploit the biomasses potentials and to follow the European tendency about energy politics for the incentive in the renewable sources, such as the biomasses. We considered the chips such as product derivable from the wood biomasses transformation and we analyzed its more important characteristics and the machines for its production. We hypothesized, analyzed and compared two hypothetic yards for the production and sale of the chips, using two different types of calculus programs.
In the first yard would support a chips cost equal to 59 €/t and would have a work capacity of 0,68 t/h; in the second yard, with a higher degree of mechanization, the work capacity would be 0,99 t/h, with a cost reduction of 23%. In the last case the convenience would have only whit a great quantity of chips, about 946 t/y, obtaining with an accurate management of the green heritage of the city.
From the results, obtained and compared with the currently public park maintenance in Potenza, it appears clearly the economical convenience of the chips chain, that must represent in future a valid instrument of investment, if supported by a correct and a regular public parks maintenance.

Keywords: public parks, biomasses, chips

Introduction

In the last twenty years the most important international organizations, such as ONU, OCSE and UE, promoted increasingly the initiatives in order to preserve the green patrimony quantity and quality of our cities and wildlife reserves, in behalf of the future generations. If on one hand more prominence to the sustainability has been given, concerning the quality life improvement, on the other hand the aspects relative to energetic recovery of the material deriving from the maintenance operations has been disregarded.
The public parks management by municipalities has been modified, joining to the direct management the outsourcing; ad hoc companies have been established as an alternative. Currently the public parks rules are lean and fragmented, devoid of an organic policy emphasizing its whole potentialities, as provider of recreational and environmental functions, moreover potential biomasses source. At present the Interdepartmental Decree n. 1444, April 2th, 1968 is the primary normative reference nationwide; the article 3 establishes the max relationships between the residential settlements spaces and the public spaces or assigned to

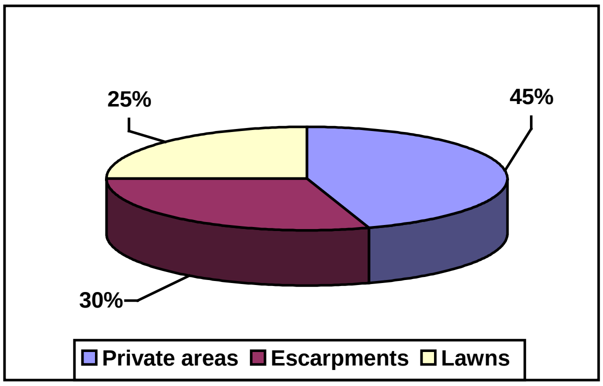
collective activities, to public parks or parking. Other normative instruments discipline specific aspects of the public parks, for example the phytosanitary struggle and the road masts. Each region can provide, with several planning instruments, more detailed such as the Plan and the Map of the public parks, as well as the Regulations that few municipalities has got, only the 23% (Sanesi G., 2001).
The aim of this work was to analyze the current public parks management in Potenza and to provide a starting point to improve this management, in order to increase the value of the waste biomasses.

Materials and methods

In the first phase of this work we characterized the public parks in the center and in the periphery of Potenza city, using maps and tables provided from the municipally. Specifically it's about these paper supports, dated back to 2002:

- *a map with the public parks topography*, that splits the city areas in numerated squares;
- *a map with the public parks numbering*, for each area has been highlighted the green belts and assigned an identification number;
- *a green table*, reporting for each area the surface, the typology (lawn or escarpment) and the property, with the possibility to trace back the exact placing of the area in the city.

For the road masts has been performed the same work, processing a *trees table* that, for each plant, reports the progressive number, an identification code, the exact collocation and the species. The total extension of the city green belts is equal to about 140 ha and according to the ISTAT dated 2008, the head surface is equal to 22,1 m^2, a quite low value if compared to the national mean. This surface presents the 45% of private areas, 30% of escarpments and the remaining 25% of lawns, as the following graph shows.



Graph 1. Green belts typologies in Potenza.

Currently the only planning instrument is the *Regulation of the public and private parks* edited in 2004, containing predominantly conservative prescriptions, as the pruning and felling modalities, with sanctions in case of non-commissioned interventions. Besides the struggle phytosanitary has disciplined on the strength of a preventive logic, promoting the adoption of not damaging means and products.
Subsequently a management analysis of the public parks carried out, in order to verify the figures which effect it and the implementation modalities. Since 2006 the city green

patrimony management is of municipally competence and has been committed to the cooperative society "Città Verde", composed by twelve member-workers and an employee; the remaining part has been managed by cooperatives engaging in the care green of the schools and the leisure centres, from the forest workers managing the peripheral city areas and from the useful socially workers. Specifically Città Verde society performs the grass and hedges cut, pruning and felling trees.
Although the municipally has a Regulation, it is lacking in a planned program of interventions relating to all city green belts in the same manner. The maintenance interventions are limited to the emergency, due to meager disposal funds.

Figure 1. Workers of the "Città Verde" cooperative at work.

With regard to the wastes deriving from the public parks maintenance the survey pointed out such as these has been accounted as a whichever urban waste, because after the picking they have been transported to apposite garbage bins posted in several city zones, where reach all typologies of urban solid wastes too. From here the material has been transported in the regional dumps placed from some tens kilometres to about an hundred, because the city dump is saturated and act as station where the material remains waiting for the transport in the regional dumps. Consequently the storage, disposal and transport costs are equal to 160 €/t, upon which weigh heavily on the transport cost.
From here rises the idea to create a city-wood-energy chain in order to recover the wood fraction to transform in chips, for a final energetic use, reducing considerably the costs that the municipally meets now, fusing the economic and environmental benefits.
The city-wood-energy chain expression indicates the organised altogether of the production, transformation, transport and utilization wood factors for the energetic purposes and in the urban environment specific case we must consider the operations beginning from the recover of the maintenance material (deriving from felling, pruning, lower branches lopping, etc.) until the wood transformation in a material suitable for the heat and electric energy production and the final use in appropriate boiler.
In order to evaluate the organization of the yard to obtain a low cost chipping, we used the ChipCost software, making possible the simulation of several chipping yards with different mechanization degree.
This program requires data entry as the weight of the middle piece for chipping, the power and cost of the chipper, the amortization period, the use of the chipper and the possible tractor connected, expressed as number of work hours per day and days number per year. These and other information have been used, from the software, to calculate the gross and net

productivity (t/h), the yard cost (€/h), the chipping cost (€/t) and the chips quantity to work annually in order to remain in this cost.

Results

In this research we considered several chains: the compost, panel, chips and firewood chains, evaluating their advantages and disadvantages. The choice of a chain in respect to another has been effected considering firstly the starting material characteristics, the presence of a demand for the produced typology biomasses and the distance of the energy plant, that should not go over 40 Km in order to an economic convenience.
The first typology chain provides the compost, like final product, obtained by a transformation and stabilization process of organic waste. It has employed as organic fertilizer for its beneficial effects on the soil, because assures an adequate bringing in organic substance, improving the fertility and containing the erosion phenomenons.
The public parks maintenance wastes with the crop residuals represent the so-called green fertilizer compost, different to the mixed fertilizer compost including the organic fraction deriving from the diversified harvest, agro-industrial activities, wood and textile processing and the animal wastes.
In an hypothetical energetic chain the waste deriving from the maintenance operations would has carried from the yard site to the composting plant. This chain would allow a total disposal of the material, with a marginal recourse to further subordinate processing, but disposal costs would support without the possibility to obtain proceeds.
The panel and chips chains envisage both the woody waste chipping with appropriate machines, the chippers, cutting into small pieces the material by a cut perpendicular to the fiber. The product obtained consists by parallelogram-shaped scraps, called "chips".
In the first chain the material would has chipped after the harvesting and transported to the panel industries, avoiding to undergo seasoning treatments. In this manner the total wastes disposal and the chips sale would execute, without to support storage costs and the material transport would be more easy thanks to low volume and the fluidity of the chips. The proceeds obtaining depend to the yard mechanization degree, to the presence of a chips market for panels, to the existence and distance of the panel industries.
The chips chain foresees the use in small-sized heat plants, such as domestic boiler, netting district heating or cogeneration plants. The economic convenience depends primarily on the mechanization degree and the presence, in a limited range, of chips heat plants.
The heterogeneous raw material represents a critical point and prevents a precise chips characterization, as the normative foresees.
In the firewood chain is necessary to separate the wood fraction from the material deriving from the maintenance operations, in order to effect the sale as combustible. For the equipping wood the yard needs to a log-splitting machine for the wood pieces of greater size. Therefore this chain involves processing quite high cost, compensated by the combustible sale price, higher as regard to the chips price. During the processing a waste quantitative has produced.
Starting on the main energetic chains comparison we come to the conclusion whereby the chips chain is the most appropriate choice, considering the total recovery of the waste material thanks to the whole tree introduction in the chipper, avoiding the preliminary equipping operations with a gain come from the biocombustible sale.
In the two hypothesized yards we presuppose the employ of a drum chipper that represents the most adequate typology to work an heterogeneous material, like that deriving from the public parks maintenance.

The chipping yards hypothesized have composed by:

- ***yard n.1*** → a drum chipper with the operative capacity equal to 15-20 m^3/h, mounted tractor of 48 kW. The members of staff are three: the first worker placed in the tractor, the second responsible to introduce the wood material in the chipper and the third for the management operations of loading and unloading chips;
- ***yard n.2*** → a drum chipper with autonomous diesel motor of 94 kW and a productivity per hour equal to 20-25 m^3 , equipped by an hydraulic crane with a lift capacity of 300 kg and a length equal to 4,20 m. The workers number is two: the first for the timber loading by crane and the second for the chips unloading.

In order to guarantee the safety we avoid the chipping yard equipping in correspondence to the maintenance yard, instead in a square situated in an easy reachable and central zone, to reduce the transport costs.

The ChipCost software applied to two yards provides these results:

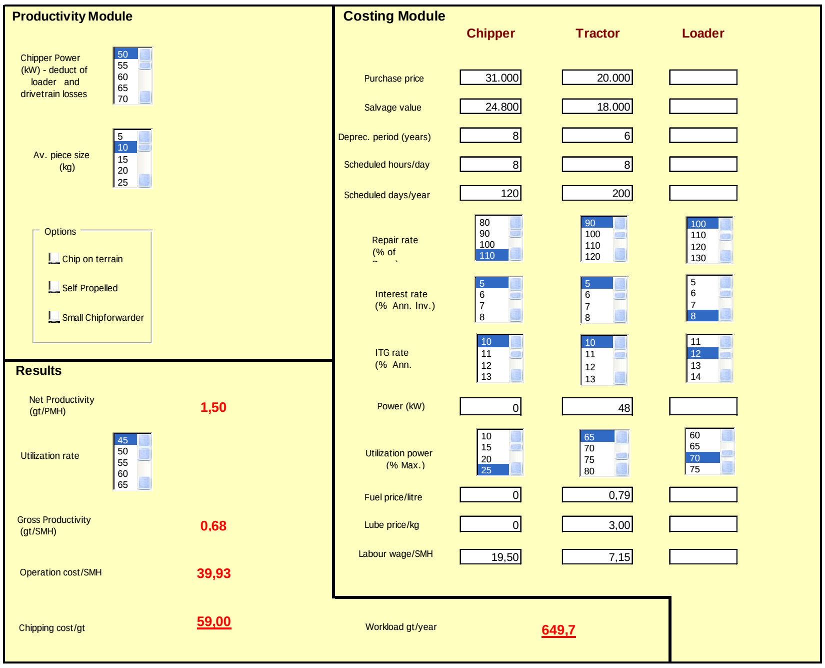


Figure 2. ChipCost applied to yard n.1.

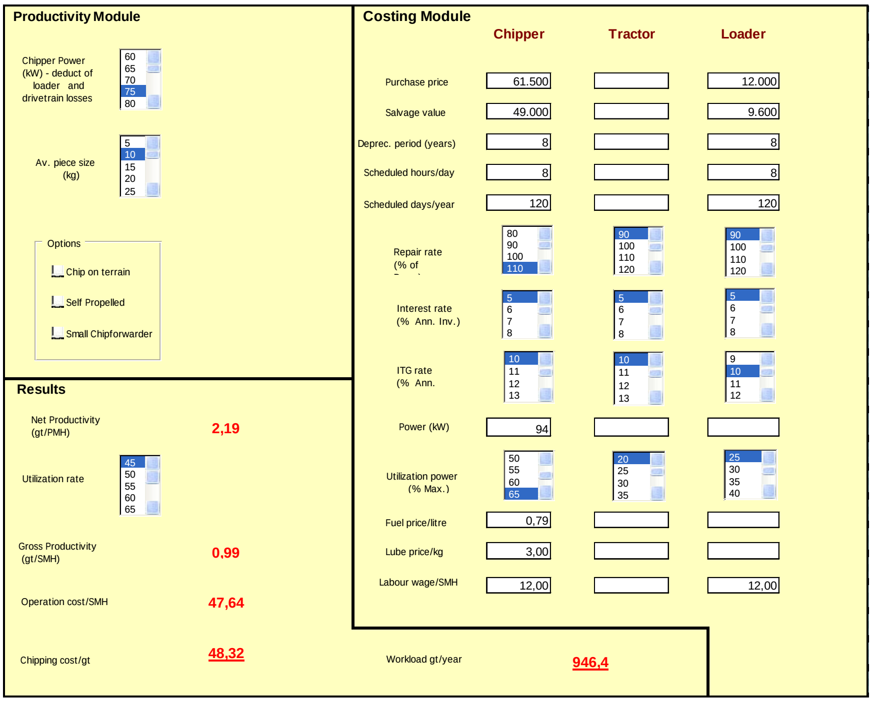


Figure 3. ChipCost applied to yard n.2.

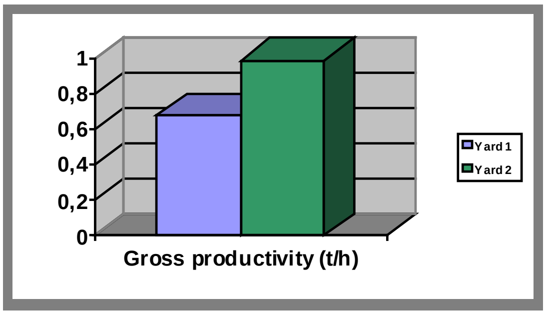
The following table resumes the main results deriving from the ChipCost applied to the chipping yards, characterized by a different mechanization degree.

Table 1. Comparison of the ChipCost results.

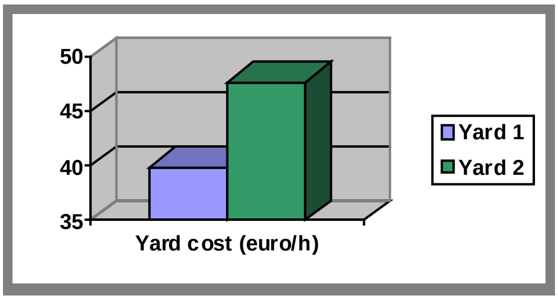
	YARD 1	YARD 2
Net productivity (t/h)	1,50	2,19
Gross productivity (t/h)	0,68	0,99
Yard cost (€/h)	39,93	47,64
Chipping cost (€/t)	59,00	48,32
Biomasses worked (t/y)	649,7	946,4

From the comparison between the yards hypothesized results as the yard n.2, with a high mechanization degree, guarantees a gross productivity, including the dead times, equal to 0,99 t/h , of 45% more high as regards to the productivity obtaining from the yard n.1, with a low mechanization degree (graph 2).

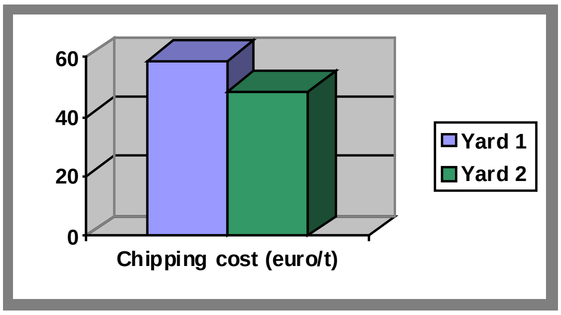
In the first yard the chipping cost is equal to 59 €/t against 48 € of the other yard (graph 4); 649,7 tons per year of chips needs to work in the first case and 946,4 tons in the second case, in order to avoid that the cost obtained exceeds the cost shown from the software (graph 5); quantitative obtainable by a regular management effected during all the year round and regarding all city green belts, included the most marginal areas.



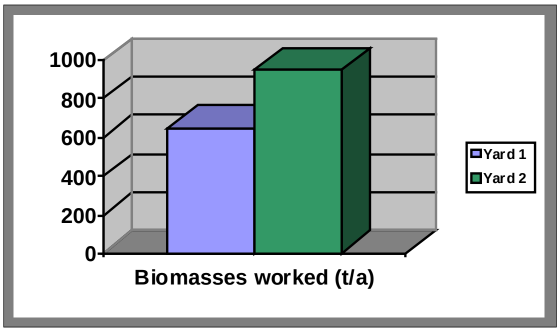
Graph 2.Gross productivity.



Graph 3. Yard cost.



Graph 4. Chipping cost.



Graph 5. Biomasses worked.

From the results obtained, the yard 1, with a low mechanization degree, represents a right compromise between productivity and costs of chips production. These costs would be very low in respect to expenses supported by municipally for the storage, transport and wastes disposal, including the public parks residuals too and the gain deriving from the sale of the chips produced needs to consider.

Conclusions

The public parks should have considered for its positive effects on the human health and as potential biomasses source. The wastes deriving from the maintenance operations have considerable energetic potentials to exploit and to constitute a source gain.
The public parks normative in force, for several aspects, is lean and has the aim to improve the environmental and recreational functions, preserving the green belt existing and planning new green areas, but there is not a national action plan concerning the energetic recovery of the wood wastes.
In Potenza city, at present, this material follow the same destination of the urban solid wastes because it has been transported to dump, meeting the transport and disposal costs, weighing on the municipal balance.
The chips chain results the most appropriate, from the analysis executed, because allows:

- to use totally the material deriving from the maintenance operations, without the further waste production, since the whole plant can be introduced in the chipper, avoiding the equipping operations;
- to obtain as product the chips, extremely manageable and, thank its fluidity, able to reduce the apparent volume of the starting material and the transport costs;
- to support the cost chipping principally, very low as compared with disposal costs.

In this way the waste biomasses retrieves its "identity" of resource, to improve and the chain hypothesized would represent a motivating force to manage the public parks efficiently, in virtue of the gain obtainable and would be an incentive to invest in this direction, considering the environmental positive outcomes.

Rerefences

Ferrini F. 2006. Forestare la città: ruoli e funzioni del verde urbano e periurbano.

GAL Prealpi e Dolomiti 2007. Linee guida per lo sviluppo di un modello di utilizzo del cippato forestale a fini energetici.

Sanesi G. 2001. Stato dell'arte della regolamentazione del Verde Urbano in Italia. Pima indagine sui comuni capoluogo di provincia. Convegno La regolamentazione del Verde Urbano 2001, 28 September 2001.

Each author contributed in this paper in same measure

Survey of the Mean Pressure Exerted by a Wide Range of Tractors on the Soil

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Abstract

In order to predict the mean pressure exerted by a vehicle tyre on the soil, in 1984 Plackett suggested measuring the contact area of a tyre on a hard surface.
The model proposed by Hallonborg in 1996, based on the "super ellipse theory", provided the best results in terms of prediction of the tyre-soil contact area.
In this study 82 4WD tractors with different power, mass and age of manufacture were surveyed. Relying on their technical features, the contact area of the front and rear tyres of each tractor and, therefore, their pressure on the soil was calculated, in order to assess the attention paid by manufacturers to soil compaction.
The results of this survey showed that the mean pressure exerted by the front tyres of a tractor is higher than that applied by the rear ones.
In addition the pressure of each tractor tyre was compared to the threshold value of 100 kPa, defined by Vermeulen and Perdok (1994) as the maximum pressure that a tyre could exert on the ground to prevent soil compaction and, relying on this value, the "threshold allowable load" was calculated.
Manufacturers seem to pay scarce attention to soil compaction caused by the tyres, especially when implements are fitted to the rear and/or front power lift.

Keywords: soil compaction, tyre-soil contact area, threshold allowable load

Introduction

Soil compaction caused by the traffic of agricultural machines has been a problem since the beginning of agricultural mechanisation. As a consequence of technological development, the power and, therefore, the mass of agricultural machines has increased, so that the soil structure is often at greater risk than the past.
In order to predict the effects of the traffic of agricultural machines on the soil, tyre-soil contact area (difficult to be measured) and tractor mass are needed.
In 1984 Plackett suggested measuring the contact area of a tyre on a hard surface. This area is different from the tyre-soil contact area, being this last one affected by highly variable factors, like soil-texture, gravel, moisture content, crop roots, plant cover, etc.
Other authors studied prediction models taking into account the tyre parameters. The model proposed by Hallonborg (1996) for calculating the tyre-soil contact area on a hard surface, based on the "super ellipse theory", provided the best results in terms of prediction of the tyre-soil contact area (Febo et al., 2000; Febo, Pessina, 2002; Febo at al., 2002; Febo et al., 2003).
This work is aimed at assessing the attention paid by tractor manufacturers to soil compaction caused by the tyres, surveying tractors of different power, mass and manufacture age.

Materials and methods

82 4WD tractors of five different manufacturers, belonging to four power categories (<50, 50-80, 80-110, 110-140, >140 kW) and four manufacture decades (1970s, 1980s, 1990s, 2000s) were surveyed.

According to the model proposed by Hallonborg, based on the tyre parameters and tractor mass, the contact area of front and rear tyres of each tractor and, therefore, their pressure on the soil was calculated.

Results

The results of this survey showed that the mean pressure exerted by the front tyres of tractors is higher than that applied by the rear ones (Fig. 1). In addition the tractors of maximum power, marketed in any decade, generally cause the highest pressure on the soil.

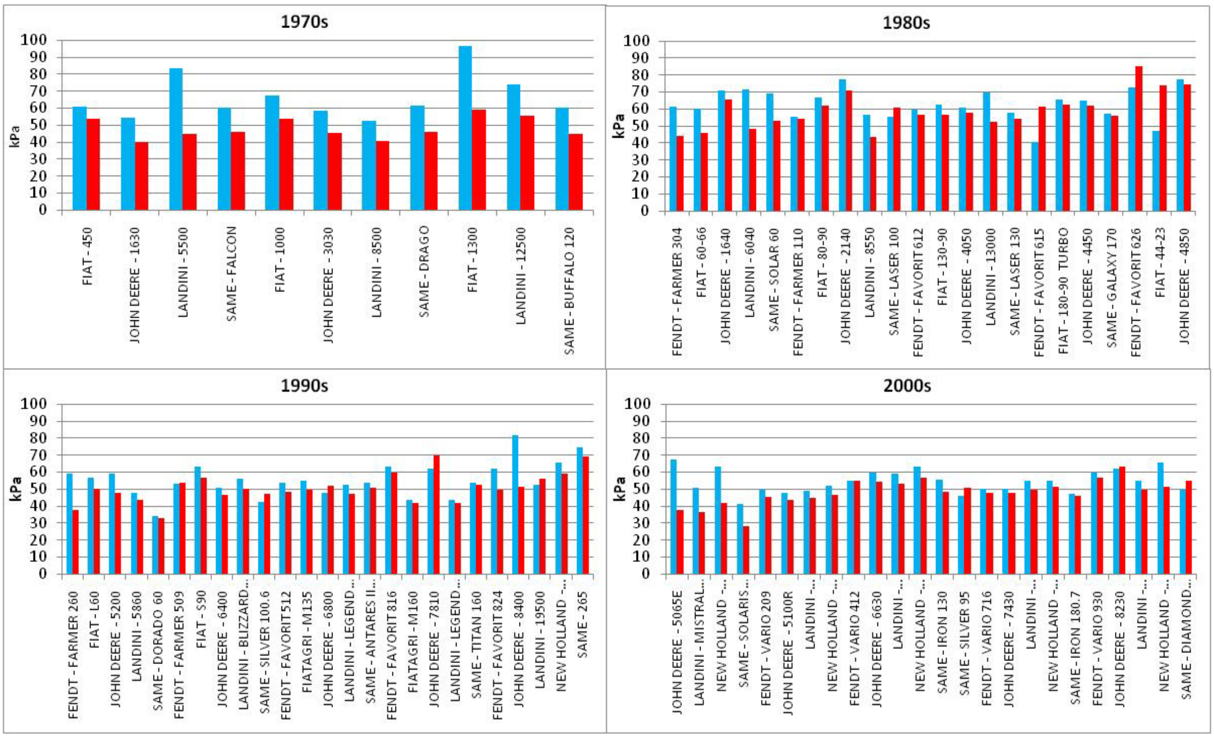

Figure 1. Pressure exerted by the front (blue) and rear (red) tyres of the tractors marketed during four decades.

The minimum, maximum and mean pressure on the soil caused by the front and rear tyres of the tractors marketed over the above decades is shown in Table 1.

Table 1. Pressure (kPa) exerted on the soil by the front and rear tyres of the tractors marketed during four decades.

	Front tyres			Rear tyres		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
1970s	53	97	66	40	59	48
1980s	41	78	63	44	85	59
1990s	34	82	56	33	70	51
2000s	41	68	55	28	63	48

The above values for each manufacturer are shown in Figure 2. The mean pressure on the soil exerted by the front and rear tyres of the tractors marketed by the five manufacturers over the four decades generally tends to slightly decrease. In the 1970s the variation range is generally low, because of the limited number of models offered by the manufacturers. For each manufacturer the variation range tends to decrease from 1980s to 2000s.

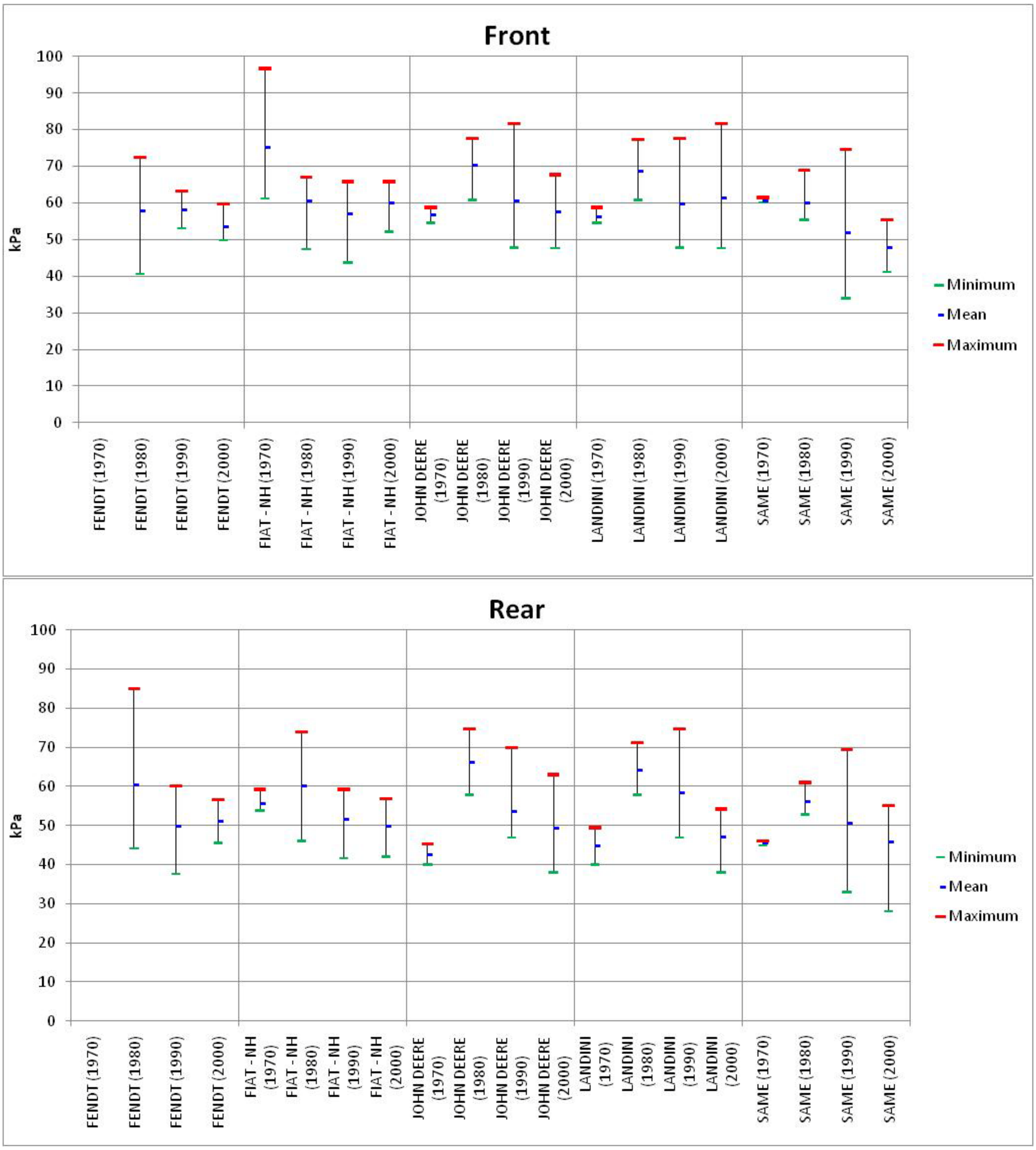

Figure 2. Pressure exerted on the soil by the front and rear tyres of the tractors marketed by five manufacturers during four decades.

The pressure of each tractor tyre was also compared to the threshold value of 100 kPa, defined by Vermeulen and Perdok (1994) as the maximum pressure that a tyre could exert on the ground to prevent soil compaction. Therefore, relying on this figure, the "threshold allowable load" was calculated.
Figure 3 shows, for each manufacture decade and power category, the load (minimum, maximum and mean) which, if added to the front and rear tyres, determines the mean pressure of 100 kPa on the ground. In the 1970s the variation range is low, because tractors in the two highest power categories (110-140 and >140 kW) were not marketed. However the "threshold allowable load" increases with increasing power.

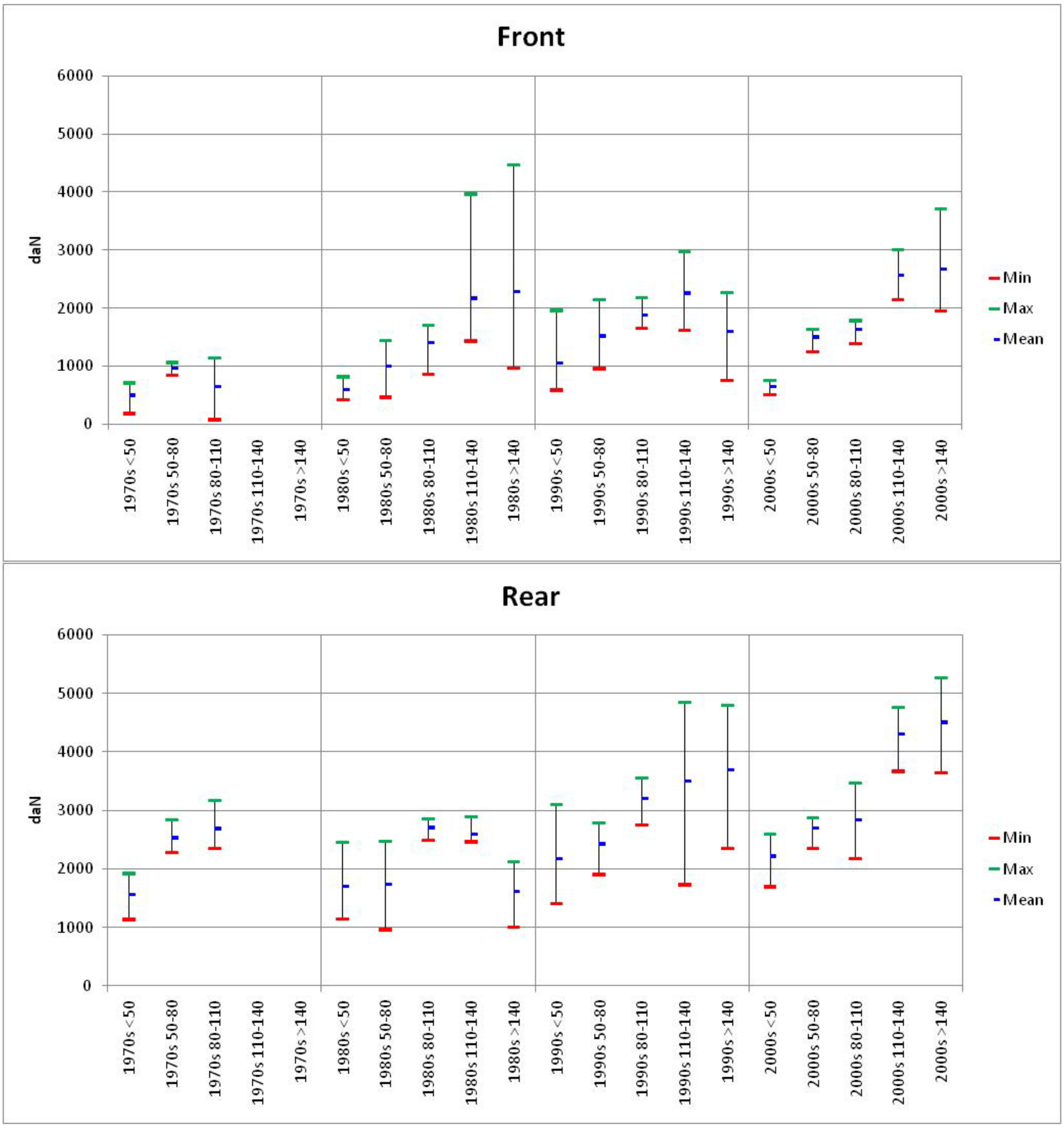

Figure 3. Load which, if added to the tractor front and rear tyres, determines the mean pressure of 100 kPa on the ground, for each manufacture decade and power category.

Conclusions

Many manufacturers advertise the amount of load that can be applied to the tractor power lift, without taking into account the soil compaction caused both by this load and the load transfer from the implement to the tractor.
This survey shows that manufacturers seem to pay scarce attention to soil compaction caused by the tyres, especially when implements are fitted to the rear and/or front power lift.
This is also demonstrated by the absence of the front tyre size in the brochures of the tractors marketed over the last decade.
It would be useful if manufacturers provided information not only on the size, but also on the mean pressures exerted on the ground both by the standard and optional front and rear tyres of their tractors.

References

Febo P., Pessina D., Lucarelli F. 2000. Soil-tyre interaction parameters influencing soil compaction: a study of contact area prediction models. In: R. Horn, van den Akker J.J.K., Arvidsson J., "Subsoil Compaction, Distribution, Processes and Consequences", Advances in Geoecology, 32, 191:201, International Union of Soil Science (IUSS), Reiskirchen, Germany.

Febo P., Pessina D. 2002. Ground pressures exerted by agricultural machines. In: M. Pagliai, Jones R., "Sustainable Land Management – Environmental Protection: A Soil Physical Approach", Advances in Geoecology, 35, 339:350, International Union of Soil Science (IUSS), Catena Verlag Gmbh, Germany.

Febo P., Pessina D., Orlando S., Vallone M. 2002. La pressione esercitata dai mezzi agricoli sul terreno. Rivista di Ingegneria Agraria, 4, 39-47.

Febo P., Pessina D., Vallone M. 2003. Soil-tyre/track interaction. A review of the last ten years studies from the soil compaction point of view. Rivista di Ingegneria Agraria, 3, 55-68.

Hallonborg U. 1996. Super ellipse as tyre-ground contact area. Journal of Terramechanics, 33 (3), 125-132.

Plackett C.W. 1984. The ground pressure of some agricultural tyres at low load and with zero sinkage. Journal of Agricultural Engineering Research, 29, 159-166.

Economic Feasibility Study of Semitransparent Photovoltaic Technology Integrated on Greenhouse Covering Structures

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Abstract
This study investigates the application of semitransparent photovoltaic (PV) technology integrated on the cover of an east-west oriented greenhouse. With reference to the average greenhouse features identified through a preliminary survey over several greenhouse farms in Northern Sardinia (Italy), the study considered the application of grid-connected PV systems based on modules with light transparency ranging from 50 to 75%. A feasibility analysis was performed with different overlay levels on the roof, in order to assess their energy potential and the economic convenience of the investment. By covering south oriented roofs only, the maximum power to be installed is between 94 and 188 kWp, corresponding to a shading level respectively of 10 and 19%. Annual electricity production of PV systems considered has been estimated between 112,800 and 260,200 kWh. Considering the yearly radiation intensity examined, the potential electrical output of PV systems, for all solutions considered, is higher than the power demand of an average floriculture farm (21,600 kWh). The best economic results have been obtained with the 188 kWp PV system, with a Net Present Value amounting to 1,112,692 €, which is much higher than the investment cost (832,000 €). Payback time ranged from 10 to 13 years, respectively for the 188 kWp south oriented and for the 94 kWp PV system installed both in north and south oriented roofs.

Keywords: energy, electricity, cultivation

Introduction

Renewable energy power plants are growing up in European agriculture, contributing to a better energy self-sufficiency and environmental sustainability of farms. The installation of these power plants should be planned considering both the energy needs of the farms and their potential role as energy producers.

Among agricultural sectors, protected cultivations are notoriously a high energy demanding activity, whose production costs are strictly depending on the energy fares trend. This problem priorities the need for energy conservation strategies, by planning energy self-production and energy-saving investments. In order to preserve the advantages of greenhouse cultivation and enhance the sustainability of greenhouse production, it can be important to reduce energy consumption and to cover or partly compensate the consumed energy with renewable energy sources (Yano *et al.*, 2009). Moreover, the quota of self-produced energy exceeding the farm needs is considered by Italian norms as an economic activity connected to agricultural production, thus generating further profits through incentive fares.

In Northern Sardinia (Italy), where greenhouse farms are mainly characterised by wide-span glass structures in 70% of total greenhouse covered area, photovoltaic (PV) panels could be easily integrated in existing structures without exploiting further surfaces for agricultural activity. The consequent shading caused by the solar generator could limit plant photosynthesis and lead to problems related to crop productivity. Recent tests carried out in an experimental farm in Liguria region (Italy) have shown no significant crop productivity loss on tomato, basil, courgette and some ornamental plants cultivated with a 20% shading caused by PV modules (Minuto *et al.*, 2009). Semitransparent PV technologies, whose surface is just partially covered with solar cells, can represent the right solution for reducing their impact on the crop. These modules are transparent to light in customisable percentage, which results in a more distributed shading inside the greenhouse. In this way the greenhouse roof can be extensively covered with solar panels, limiting light radiation loss at the same time. During summer periods, integrated semitransparent PV panels could also contribute to a better thermal balance of the greenhouse, since it reduces the internal solar load and the air cooling demands.

This paper analyses the energy and economical performance of a greenhouse prototype with semitransparent PV modules integrated on the cover. The prototype has been dimensioned following the results of a preliminary field survey on greenhouse farming in Northern Sardinia. A feasibility study was performed to assess the economic convenience of a grid-connected PV system, covering less than 20% of total roof area, as to reduce the influence of shading level on crop productivity.

Materials and methods

The main features of the greenhouse sector in North Sardinia have been defined by visiting 58 greenhouse companies in 2008. The following data have been collected from each floricultural and horticultural farm: area and number of greenhouses; construction types and age; main cultivation techniques; electrical and thermal energy consumption; type of conditioning and irrigation facilities. Thus, the greenhouse type representing the average characteristics of the sector has been outlined and used for designing the PV system. The solar power generator was planned by considering two semitransparent photovoltaic modules (fig. 1), specifically designed for glass greenhouse covers, with different density of solar cells and transparency level (tab. 1): the first one with 90 Wp power module and 50% transparency level (Solarkey DG 6M24/T), the second with 45 Wp power module and 75% transparency level (Solarkey DG 6M12/T).

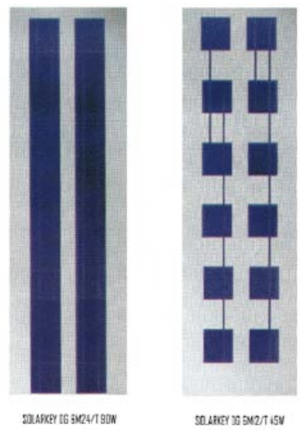

Figure 1. Distribution of solar cells on PV semitransparent modules.

Table 1. Characteristics of semitransparent photovoltaic modules considered in the feasibility study.

	SOLARKEY DG 6M24/T	*SOLARKEY DG 6M12/T*
Solar cell technology	polycrystalline silicon	
Solar cell per module (°n)	24	12
Solar cell efficiency	15%	
Cell format (mm)	156 x 156	
Module efficiency η_m	7.50%	3.75%
Maximum power (Wp)	90	45
Maximum power voltage (V)	12.12	6.2
Maximum power current (A)	7.43	
Dimensions (mm)	2000 x 600 x 5	
Transparency	50%	75%

These modules are characterised by having the same width of the common greenhouse glass panes (600 mm), thus power plant integration on the roof would be simple and cheap. Four different solutions have been outlined when planning the PV systems, depending on the module peak power (45 Wp or 90 Wp) and the percentage of greenhouse roofs covered, which can be north (N) and/or south (S) oriented roofs. The efficiency of the PV systems was calculated as function of the module efficiency (η_m) and the average overall derate factor (η_o), defined as follows:

$$\eta_o = \eta_a \cdot \eta_b \cdot \eta_c \cdot \eta_d \cdot \eta_e \cdot \eta_f \cdot \eta_g \cdot \eta_h = 0.747$$

where:

η_a = Initial light induced degradation (0.98)
η_b = DC and AC wiring (0.97)
η_c = Diodes and connections (0.995)
η_d = Mismatch (0.98)
η_e = Inverters and transformers (0.931)
η_f = Soiling (0.98)
η_g = Shading (0.96)
η_h= Temperature effect (0.92)

Shading factor (η_g) has been estimated as 0.96 for transitory shading effect caused by ridge window openings. Average annual efficiency loss is 0.4% within 20 years and 2% between year 21st and 30th, considered as the limit for PV systems lifetime. The annual radiation (R) has been calculated using the UNI10349 standard, amounting to 1853 kWh/m^{2}y for S oriented areas and 1360 kWh/m^{2}y for N oriented areas, considering a tilt angle of 25°. The average annual energy production per kWp can be calculated considering the area covered by 1 kWp (S):

$$E_{1kWp} = S \cdot R \cdot \eta_m \cdot \eta_0 \ \textit{(kWh/year)}$$

PV systems planned use both N and/or S oriented greenhouse roofs.

Economic analysis has considered investment unit costs of 4300 €/kWp and 4500 €/kWp, respectively for less and more than 100 kWp total power and considering the financial incentives of the national program "Conto Energia 2010". This program for stimulating PV energy production provides a feed-in tariff incentive, depending on the power and the integration factor in buildings. The 2010 incoming feed-in tariff for PV plants examined is 0.422 €/kWh, corresponding to the incentive for completely integrated PV generators, where solar panels replace parts of a building or structure. In this case, solar panels are used as greenhouse coverage instead of common glass panes. This tariff is supplied for all PV energy produced, while the energy sale tariff (0.108 €/kWh) is supplied for the quota of energy fed into grid only.

Results and discussion

Protected cultivation in North Sardinia is mainly dedicated to horticulture (22.8 ha), while floriculture occupies 9.7 ha. The most diffused greenhouse type is the wide span glass greenhouse (72%), followed by plastic type (10.5%) and tunnels (7.2%). The average covered area per farm has found to be around 6000 m^2 both for horticultural and floricultural cultivations. Soil cultivation was used in almost 80% of visited companies, while 22% used benches and only 1.7% used hydroponic technique. Heating is mainly supplied through direct-fire units consuming diesel oil (90%), while the remaining farms used heating systems with centralized hot water boilers. Internal shading curtains and energy-saving screens were installed in 22% of farms, while only 5.5% were provided with fog and fan evaporative cooling systems.

Total electricity power supply of investigated farms accounted for 620 kW, corresponding to an average of 11 kW/farm. Annual electricity consumption was estimated in 480,000 kWh_e/y for horticultural farms (2.2 kWh_e/m^2y) and 350,000 kWh_e/y for floricultural farms (3.6 kWh_e/m^2y). These values are within the average electrical consumption of a typical Mediterranean greenhouse, where power electrical demand ranges from 90,000 kWh_e/ha in greenhouses with a good climate control, to 20,000 kWh_e/ha for very low technological greenhouse structures (Campiotti *et al.*, 2008). Thermal power installed in all farms amounted to 23.9 MW_t. Thermal energy consumption was estimated through oil bills in 48.5 MJ/m^2y, reaching up to 79.1 MJ/m^2y for floricultural greenhouses.

In order to dimension the PV system, A 6000 m^2 multi-span glass greenhouse has been hypothesized, formed by two blocks east-west oriented. Each block (3000 m^2) is formed by 3 spans with pitched roof and the following dimensions: 9.60 m width, 104.40 m length, 3.00 m gutter height, 5.24 m ridge height, 5.30 m roof width, 1.30 m ridge window width, 25° roof slope. Excluding the ridge window area to allow internal ventilation, the PV modules can replace glass panes in each roof occupying a maximum surface of:

$$PV\ area = (5.30\ m - 1.30\ m) \cdot 104.40\ m = 417.60\ m^2$$

This PV area covers 75.5% of one roof. Considering the module dimensions, the maximum number of solar modules that can be installed results:

$$417.60\ m^2 / (2.00\ m \cdot 0.60\ m) = 348\ modules\ per\ roof$$

These PV modules can be placed either on the S oriented roofs only, or equally distributed between the S and the N oriented roofs, in order to have a more even internal shading area, with slightly higher solar radiation for the crop, without modifying the overall cover percentage (fig. 2). According to this, four hypothesis have been considered when designing the photovoltaic PV systems:

A. 90 Wp modules, covering all six S oriented roofs (2088 modules) corresponding to 188 kWp power;
B. 90 Wp modules, equally distributed on S and N oriented roofs (1044+1044 modules) corresponding to 188 kWp total power;
C. 45 Wp modules, covering all six S oriented roofs (2088 modules) corresponding to 94 kWp power;

D. 45 Wp modules, equally distributed on S and N oriented roofs (1044+1044 modules) corresponding to 188 kWp total power.

To calculate the different internal shading level, the roof coverage (75.5% in all design solutions) and light transparency of the modules should be considered. With the 90 Wp module (A and B solutions), characterized by 50% light transparency, the shading level referred to the entire greenhouse is about 19%: this value decreases to 10% when 45 Wp modules with 75% transparency are used (C and D solutions). Considering the energy production of 1384 kWh/kWp per year on S oriented PV generators and 1016 kWh/kWp per year for N oriented ones, the amount of electricity potentially produced by the different solutions is shown in table 2. Solutions A and B, both with S orient modules, provide 260,228 kWh/year and 130,114 kWh/year respectively. When modules are installed on both N and S roofs, the electricity production decreases of about 13%.

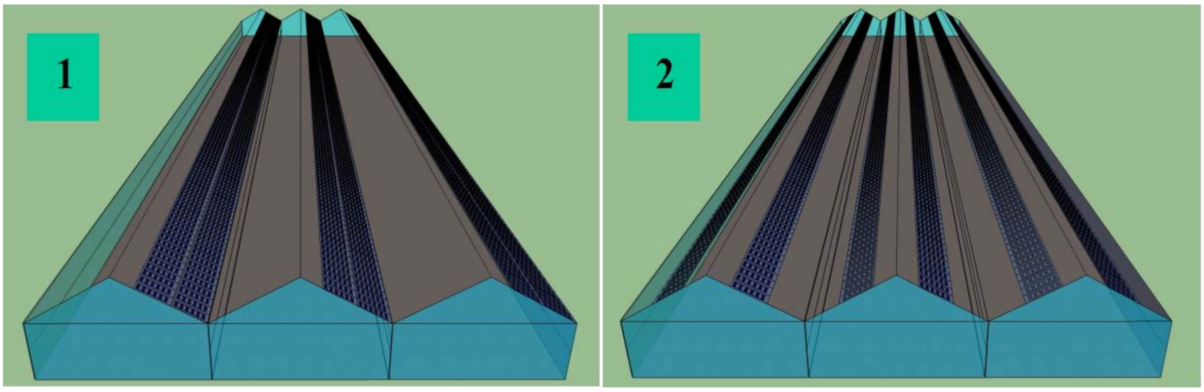

Figure 2. PV generator placing: 1) PV modules installed on S oriented roofs as solution A and C. 2) PV modules installed by equally covering N and S roofs, as solution B and D. Shading level is 10% or 19% depending on the PV module used.

To evaluate the economic results of designed PV systems (tab. 2), the following economic indicators have been considered:

- Net Present Value (NPV), calculated by the formula:

$$NPV = \sum_{1}^{n=20} \left[\frac{CF(1+i)^n (1+e)^n}{(1+r)^n} \right] - I_o$$

where:

CF = annual cash flow (€)	*r = bank discount rate (5.7%)*
i = inflation rate (2%)	*n = years*
e = energy inflation rate (3%)	*I_o = investment cost (€)*

- Internal Rate of Return (IRR), calculated as ratio between NPV and investment cost;
- Pay-Back Time (PBT), number of years needed to cover the investment cost.

NPV and IRR are evaluated within 20 and 30 years from installation. Most part of energy produced is sold to increase the overall annual income. However the PV systems supply energy for the farm too. Considering the estimated average electricity demand of 3.6 kWh/m^{2}y per farm, the annual energy consumption corresponds to about 21,600 kWh/y for a 6000 m^2 greenhouse. This requirement is much lower than the energy production of every PV systems considered. For example, in the A solution the electricity yearly produced by the 188 kWp system amounts to more than 260,000 kWh/y, which is 12 times more than the annual energy expenditure, providing further profits for the farm.

Investments are economically convenient for all solutions considered. NPV is always positive, showing that the investment is profitable. The highest positive NPV values are achieved with solution A and C, amounting to approximately 130% of the initial investment, while solution B and D amount up to 96%. Investments in photovoltaic energy is even more convenient if specifically applied in greenhouses: if the PV system power is less than 200 kW, the energy production is considered as connected to the main greenhouse business, with consequent tax relieves (Burchio, 2010).

IRR and PBT differ depending on the chosen solution, but always show economic convenience. A and C solutions have been found to be the most convenient ones, since NPV and IRR show the highest values compared to the other two solutions. Solution B and D (with both S and N roofs covered) allow to have a more distributed internal shadow on plants, but are slightly less convenient: covering N oriented roofs causes a solar radiation capturing decrease, which lead to a 13% energy production loss. While 1384 kWh were yearly produced by every kWp S installed, energy production decreases by 26% using N oriented roofs.

PBT of 10 years confirms the convenience of solution A and C, compared to B and D, ranging from 12 to 13 years. A payback time of 10 years is considered as a good value by PV designers, which is going to decrease in the nearly future, thanks to the constant reduction of PV technology cost. Similarly, the energy production cost is cheaper in solution A, because of the lower specific cost of the PV system (4300 €/kWp instead of 4500 €/kWp), which is connected to scale economies related to the dimension of the PV power plant.

Conclusions

Investing in PV systems installed on greenhouse roofs often focuses only on maximizing electricity production, without considering the loss in solar radiation availability for crops, when modules cover the total roof area.

This paper showed how to integrate energy on a greenhouse, limiting internal light radiation loss and avoiding significant decreases in protected crop productivity. This aim can be achieved by using PV modules specifically developed for greenhouse use, based on semitransparent technology, which can replace greenhouse glass panes. Integrated PV systems installed on S roofs provide energy amounts which are much larger than the needs of electricity of the entire farm. Installations on both S-N roofs allows a more uniform internal shading, considered on annual basis, but it makes the investment less convenient.

These power plants should be installed to provide electricity for satisfying the farm energy requirements, reduce energy costs and add further profits to the main agricultural activities, by selling the exceeding electricity produced. PV energy production in agricultural areas should be configured not as an independent business, but as a profitable activity connected to the main agriculture income of a commercial greenhouse company.

Table 2. Technical and economical comparison among the four PV systems considered.

PV system summary		***A***	***B***	***C***	***D***
Module power	***Wp***	**90 Wp**	**90 Wp**	**45 Wp**	**45 Wp**
Module light transparency	***%***	**50**	**50**	**75**	**75**
Greenhouse roofs covered	-	**south**	**south/north**	**south**	**south/north**
Total PV system power	***kWp***	**188**	**188**	**94**	**94**
PV area	***m^2***	**2,507**	**2,507**	**2,507**	**2,507**
Energy production	***kWh/year***	**260,228**	**225,618**	**130,114**	**112,809**
Shading level	***%***	**19%**	**19%**	**10%**	**10%**
Economic summary					
Investment cost	**€**	**832,000**	**832,000**	**434,850**	**434,850**
Feed-in tariff contribute (0.422 €/kWh)	**€**	*109,816*	*95,211*	*54,908*	*47,605*
Energy sale income (0.108 €/kWh)	*€*	*25,772*	*22,034*	*11,720*	*9,851*
Energy bills saved (0.165 €/kWh)	*€*	*3,564*	*3,564*	*3,564*	*3,564*
Total annual income	**€**	**139,152**	**120,809**	**70,192**	**61,020**
Taxes (IRES 27.5%, IRAP 1.9%)	*€*	*7,577*	*6,478*	*3,446*	*2,896*
Maintainance (1.4%)	*€*	*11,648*	*11,648*	*6,088*	*6,088*
Insurance (0.6%)	*€*	*4,992*	*4,992*	*2,609*	*2,609*
Energy deposit withdrawal (4%)	*€*	*1,031*	*881*	*469*	*394*
Withdrawal energy costs (5%)	*€*	*1,421*	*1,248*	*771*	*684*
Total annual costs	**€**	**26,669**	**25,247**	**13,382**	**12,671**
NPV 20 years	**€**	**1,112,692**	**805,024**	**566,619**	**412,785**
IRR 20 years	-	**1.34**	**0.97**	**1.30**	**0.95**
NPV 30 years	**€**	**1,096,183**	**772,072**	**597,393**	**435,338**
IRR 30 years	-	**1.32**	**0.93**	**1.37**	**1.00**
PBT	***years***	**10**	**12**	**10**	**13**
Energy production cost	***€/kWh***	**0.249**	**0.281**	**0.256**	**0.289**

References

Agenzia delle Entrate, dispatch N°32/E, 2009. Italian National Tax Office, 2009.

Burchio S., 2010. Integrare il reddito agricolo con il fotovoltaico sulla serra. Supplemento a l'Informatore Agrario, 17, 12-14.

Campiotti C, Dondi F., Genovese A., Alonzo G., Catanese V., Incrocci L., Bibbiani C., 2008. Photovoltaic as Sustainable Energy for Greenhouse and Close Plant Production System. Proc. IW on Greenhouse Environment Control and Crop Production in Semi-Arid Regions. Acta Horticulturae, 797, ISHS 2008.

ENEA, Agency for New Technologies, the Energy and the Environment. 2010. www.enea.it

GSE, National Electrical Services Manager. 2010. www.gsel.it

Marion B., Adelstein J., Boyle K., Hayden H., Hammond B., Fletcher T. Canada B., Narang D., Shugar D., Wenger H., Kimber A., Mitchell L., Rich G., Townsend T. 2005. Performance Parameters for Grid-Connected PV Systems. 31st IEEE Photovoltaics Specialists Conference and Exhibition. Lake Buena Vista, Florida (USA), January 3-7, 2005.

Minuto G.,Bruzzone C., Tinivella F., Delfino G., Minuto A., 2009. Fotovoltaico sui tetti delle serre per produrre anche energia. Supplemento a L'Informatore Agrario, 10, 16-21.

Solarkey, Solar Energy Technology. 2010. www.solarkey.it

Yano A., Furue A. Kadowaki M., Tanaka T., Hiraki E., Miyamoto M., Ishizu F., Noda S., 2009. Electrical energy generated by photovoltaic modules mounted inside the roof of a north-south oriented greenhouse. Biosystems Engineering, 103, 228-238.

The Harvest of Table Olives from the Plant by Means of an Hand Harvester

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Abstract
The production of table olive showed in Sardinia an increase of production in line with the national production (+17.3%) unfortunately the low mechanization level penalizes the sector strongly. Problems which priority have to be faced are bound to the damage induced by the work organs and especially the material which they are coated with from their conformation. The study has the aim of evaluating the mechanical damage produced by a hand harvester modified for the harvest of olives by the plant. The hand harvester is constituted from a narrow and light comb with 11 teeth in titanium with 4 mm diameter and coated by a sheath in silicone of the thickness of 1 mm for the experimentation the silicone covering was removed, some theet coated with vulcanized rubber of the thickness of 3 mm, 10 mm and 15 mm were produced and various rotation speeds were tested (200, 300 and 400 RPM). The number of turns was determined by the mechanical revolution counter (DEUMO 2) making one of the two electrical units of measurement change (v, to A). The damage produced by modified teeth on olives was ranging from a minimum of 4.2% with speed of 200 RPM. and a protection of 15 mm to a maximum of 21.3% with 400 RPM speed and protection teeth of 15 mm.

Key words: tables olives, damage, mechanical harvesting

Introduction
The table olive sector is one of great importance in Italy. According to the latest data on commerce (ISTAT), in the three-year period from 2006 to 2008, Italy produced 68,452.7 t of table olives (+11%) and processed them with the "Greek natural" "Seville" and "green" methods. In Sardinia, the production of table olives has seen an increase in line with the rest of Italy (+17.3%), owing mostly to the renovation of old processing plants and the planting of new varieties with a two-fold attitude. The most widespread cultivars are the "Bosana", the "Manna" (Fig. 1) and the "Niedda", followed by "Maiorca", "Sivigliana" and "Pizz'e Carroga". All these varieties have shown an excellent propensity for processing using different technologies, among these the "natural" or "traditional" system.[1] Harvesting is the final stage of in-the-field production and if performed at the wrong time and in the wrong way

Figure 1. Olives of the "Manna" variety picked and calibrated by hand

[1] "Natural" processing consists of removing the bitterness of the drupes in solutions of water and salt in concentrations that vary from 6 to 10%.

it may impact on the economic return of producers. Two aspects of primary importance which come before processing are thus connected to how and when table olives are harvested. Both are important since on them depend the quality and thus the market value of the processed olives. Damage to the drupes during picking, transport and processing represents one of the main causes of losses in quality and their value. At present, the harvest of table olives for "green" processing takes place prevalently by hand since, besides the calibre, lesions, abrasions and bruising of the skin of a fruit gathered even with the harvesting system used determines the depreciation of the product. This aspect is of fundamental importance, so much so that many researchers and producers have invested large amounts of money in the search for techniques capable of classifying damage by means of artificial vision systems (Diaz et al., 2000, 2004; Mateos et al., 2005; Barreiro et al., 2003) compared to selection by hand. In the case of table olives, these are the most important factors to take into consideration in introducing a mechanical harvesting system. Harvesting efficiency and the percentage of olives that fall following mechanical vibration, the arrangement of drupes and their position on the branches become secondary in importance, while they are indispensable in the harvesting of olives for the production of oil. At the base of the introduction of machinery is undoubtedly the high cost of labor, which is further aggravated by a shortage of workers. However, at present there is no alternative to the system of harvesting table olives by hand and consequently when profits are unsatisfactory the product is destined to the production of oil. Thus these two factors have caused certain producers to invest in the research and development of mechanical olive harvesting systems. The issues involved, which must be addressed with the highest priority, are connected to the damage inflicted by the movement of the working organs, the material with which they are covered and their shape. This work thus has the purpose of evaluating damage produced by a labor-saving machine (comber) on table olives according to the following points: a) the best thickness for the protection of the working organs used (teeth); b) the working parameters: velocity, thickness and distance**,** with the three types of combers compared to that having a thickness of 1 mm; c) classification of the damage produced on the drupes by the plastic material used to protect the teeth of the comb.

Materials and methods

Characteristics of the experimental field, sampling of biological material and determination of damage during harvesting

The farm where the experimental field was located was in the place known as “Mes’e Rios” at approximately 40 km from the Department of Agricultural Engineering of the University of Sassari. It consisted of an overall surface area of six hectares planted exclusively with olive trees with a two-fold attitude or destined for processing as table olives exclusively. The “Manna” variety occupies approximately one hectare of the overall area. The trees are of the same age (5 years) with an estimated production per plant between 5 and 8 kg and reach a maximum height of 2.5 m, suitable for hand

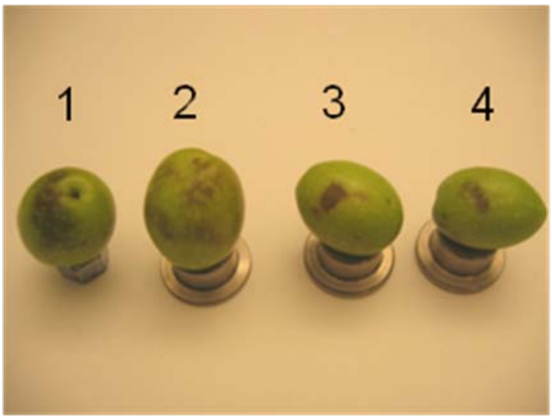


Figure 2. Example of damage caused by the Olivella Pick-Machine

picking. Overall, 36 olive trees were sampled and from each of these 4 kg of olives were harvested, following which the parameters necessary for their classification according to the COI (COI/OT/NC no. 1 December 2004) standard were determined. All the olives gathered were selected by hand and the following were determined: number per kilo, the percentage of healthy drupes, the percentage of those with biological damage (FAO 1987, USDA 1967), of those with rubbing damage (drupes that could be processed and with slight oxidation) and those that could not be processed due to excessive oxidation caused by striking with the comb or by slight injuries caused by striking the collecting boxes.

Table 1. Attributes of the screening design.

Number of experimental factors: **3**				
Number of responses. **1**				
Factors	***High***	***Low***	***Unit***	***Continuous***
Velocity	-1.0	1.0	rpm	Yes
Thickness of protection	-1.0	1.0	mm	Yes
Distance between teeth	-1.0	1.0	mm	Yes
Responses				
Damage				

Table 2. Experimental tests performed with different velocities, thicknesses and distances between teeth.

Test	Block	Replication		Velocity (rpm x 10^3)	Thickness (mm)	Distance (mm)
		Plant	Plant			
1	1	1	2	2	7	2
2	1	1	2	4	19	2
3	1	1	2	4	7	6
4	1	1	2	2	19	6
5	1	1	2	3	14	4
6	1	1	2	3	14	4
7	2	1	2	4	7	2
8	2	1	2	2	19	2
9	2	1	2	2	7	6
10	2	1	2	4	19	6
11	2	1	2	3	14	4
12	2	1	2	3	14	4

The mechanical damage caused by machine harvesting consisted of impact damage as defined by Moshenin (2000) for fruits harvested with mechanical systems and classified into four types (Fig. 2): (1) drupe-drupe rubbing following vibration; (2) drupe striking drupe; (3) comb tooth striking the drupe and (4) drupe striking the collector box. To better define the origin of impacts (with the collecting box, random rubbing or contact with the comb teeth) and the area of contact between the machine and the drupe the olives were exposed to air in the twenty-four hours following picking so as to favor the appearance of non-enzymatic oxidation phenomena caused by the different kinds of impacts described above. The experimental screening design was obtained with "Statgraphic centurion XV" software (Statpoint Inc.) using a factorial in two blocks ($2^{\wedge 3}$) and with an experimental design that called for the use of three factors (velocity, thickness and distance between teeth) and a single response (damage) according to the combination shown in Tables 1 and 2.

Characteristics of the pick machine (Olivella MINI 105 C) used in the experiments.
The labor-saving machine produced by the COIMA Italy srl, company consists of a narrow, light comb with eleven undulating titanium teeth having a diameter of 4 mm protected with a silicon cover having a thickness of 1 mm. For the experiment the silicon cover was modified and the teeth were covered with vulcanized rubber having thicknesses of 3, 10 and 15 mm (Fig. 3).
The pick machine is driven by a battery-powered (12 V) electric motor with a consumption of 5 Ah/h. The electric comb has a width of 17.5 cm and a varying number of teeth were inserted, from a maximum of 10 with the 1 mm silicon protection to a minimum of 6 in the comb with the vulcanized rubber protection with thicknesses of 3, 10 and 15 mm (Fig. 4).
The electric motor of the Olivella MINI 105 C was powered by a portable generator and connected to a power source (ISO-Tech) (12V, 30 A) for regulating the number of rpms of the teeth around their rotation axes, while the number of rpms was determined by means of a DEUMO 2 mechanical tachometer by varying one of the two units of measurement (V, A) (Fig. 5 "a" and "b").

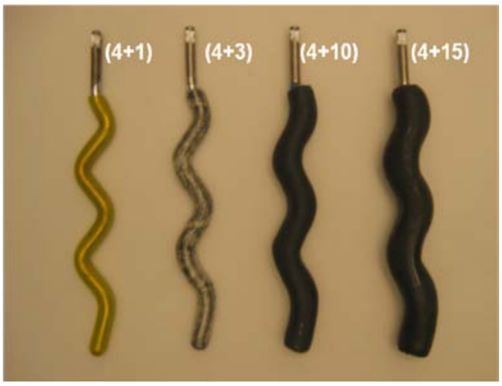


Figure 3 Modified titanium combs with different thicknesses (mm).

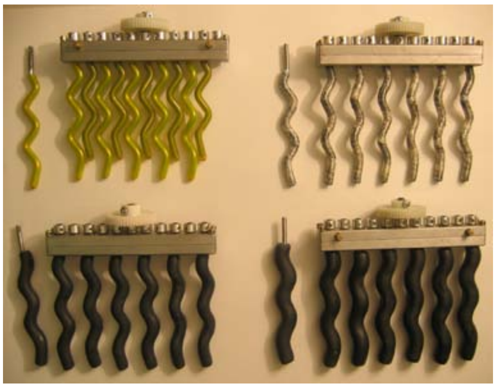
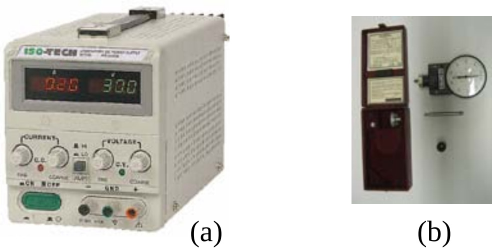


Figure 4. The complete combs with the different thicknesses used.



(a) (b)

Figure 5. The ISO-Tech power supply (a) and the DEUMO 2 mechanical tachometer (b).

Results and discussion

Product calibration
The 24 samples collected were classified according to the COI standards for table olives with the different teeth used, and of these, 12 belonged to the calibre 11 class (54%), 10 to class 12 (42%) and only two belonged to the classes 10 and 14 (4% respectively). On the basis of the number of fruits per kilo, the drupes had medium to large sizes with a number of drupes per kilo between 181 and 200 (classe 11) and 231 to 260 (class 12) as shown in
These sizes are the most suitable for processing as table olives since as is known, consumers

prefer olives with these size characteristics and with an average weight between 3 and 5 grams. In fact, the average weight of 100 olives in the two replications varied from a minimum of 3.66 g of sample 5 of replication no. 1 to a maximum of 5.51 g of sample 9 of replication 2. The percentage of drupes below size was negligible, about 2%, in almost all the samples collected and in any case this small percentage was not discarded, but was destined for processing in brine.

Table 3. Samples, size class and average weight of drupes collected in the two replications

Test number	Sample	Manna	Manna size class		Manna Average weight	
	Replication 1	Replication 2	Replication 1	Replication 2	Replication 1	Replication 2
	no. of olives/kg	no. of olives/kg	class	class	G	g
1	217	222	11	11	4.75	4.50
2	249	237	12	10	4.50	4.83
3	215	208	11	11	5.00	5.10
4	242	214	12	11	4.33	4.67
5	300	238	14	12	3.66	4.20
6	204	201	11	11	4.92	5.03
7	252	231	12	12	4.10	4.33
8	242	243	12	12	4.24	4.12
9	232	208	12	11	5.40	5.51
10	202	209	11	11	5.00	4.78
11	191	232	10	12	5.55	5.30
12	217	222	11	11	4.37	4.44

Evaluation of damage caused by mechanical harvesting

Harvesting was performed by a single worker who worked for 30 minutes on each plant. The yield was approximately 4 kg of olives per plant. Mechanical damage to the drupes was of two kinds: breakage, cuts, rubbing) externally and mostly enzymatic browning (EB) internally. The browning was directly visible and this made it possible to discard the damaged drupes during the harvesting and selection of the product. Browning takes place in the layers under the skin of the drupes following enzymatic reactions (oxidation of ammino acids by polyphenoloxidasis) when the cell membrane is broken following a mechanical impact.
The factors involved in mecanical damage to drupes depend on the characteristics of the machines used for harvesting and the way they are used, transport and processing of the product. From the tests carried out (Table 4) the number of drupes per kg and healthy drupes varied from a minimum of 761 olives/kg (test 11) to a maximum of 1077 fruits/kg (test 5). The percentage of healthy drupes varied from a minimum of 47.1% in test no. 6 to a maximum of 86.8 % in test no. 8. As can be seen in Table 4, damage is connected with the operating conditions of the picking machine, the variety and the way the machine is handled by the operator during harvesting operations. If we compare the two tests performed with different velocities and kinds of protection, they show an increase in damage of +39.7%, test

2 compared with test 8, while tests 11 and 12 are distanced from the latter by 7.6% and 10.1% respectively. Comparison of tests 8 and 2 (same velocity and protection) shows a decrease of 34.1% in the healthy product harvested. The tests performed with intermediate velocities and thicknesses of protection (tests 5, 6, 11 and 12) show a percentage of healthy product above 70% in the latter three and close to 50% in test no. 5, which is the one with the highest number of drupes per kilo. Damage produced during machine harvesting is summarized in Table 5. Biological damage varied from a minimum of 0.4% in test 11 to a maximum of 3.5% in tests 3 and 9. Classification of biological damage was made on the basis of FAO Directive 1987 and the USDA 1967 classification. For the most part, the olives presented damage caused by external agents such as temperature and humidity ("agostado or wrinkled olives") and damage caused by meteorological phenomena ("granizo or hail-damage") and lastly damage of undefined origin ("molestado or undefined damage") caused by the interaction of different factors. Damage found following the rubbing together of drupes varied from a minimum of 6.9% in test 8 to a maximum of 37.6% in test 6. The high percentage of oxidated drupes was due prevalently to the excessive number of branches on the trees and thus to involuntary impacts between drupes during harvesting. Damage produced by impacts against the collecting boxes (wounds) was 0.3% in test 8 and 3.6% in test 10. The reduction of this kind of damage, caused prevalently by the high kinetic energy reached by the fruits during the vibration and detachment stages, may be obtained by devising and adopting specific interception systems for use in combination with the harvesting machine so as also to improve the working capacity of the operators. Finally, oxidation due to impacts with the harvesting system (combs), varied from a minimum of 3.5% in test 8 to a maximum of 20% in test 2. The reduction of contact damage is possible by varying the thickness of the protection of the teeth, but also by varying their rotation velocity. Test 2, with a rotation of 2 x 10^3 rpms and the maximum tooth protection (19 mm), had the highest percentage of impact damage.
The causes of damage are mainly three: the highest number of fruits per kg, the highest average weight and size of the drupes which, during the combing of the plant, strike the others or are pressed while passing through the interaxes of the working organs. The total of drupes that could not be processed was minimum in test 8 (3.8%) and maximum in test 2 (21.7%). Considering all the tests carried out, as many as five presented a percentage of drupes unsuitable for processing below 10% while the remaining ones were between 13% and 20%.

Conclusions

In conclusion, it can be stated that the screening test performed to establish the best operating conditions for the harvesting of table olives with a picking machine, the best rotation velocity and protection, has produced encouraging results. The test showing the lowest level of damage was test 8 with a rotation velocity of 2 x 10^3 rpm and with a protection thickness of 19 mm. The tests performed with a velocity of 3 x 10^3 rpm and a thickness of 14 mm show a good performance with damage percentages between 8% and 13%, but in any case they were worse than all the other tests carried out. The system for protecting the teeth can be further improved by using other kinds of plastic materials, while for the system of interception specific solutions that call for either the use of an under canopy system or one brought directly by the operator are being studied.

References

1. Barreiro, P., Moya, A., Ruiz-Altisent, M., Agulheiro, A. C., Garcıa-Ramos, F. J., Homer, I., Moreda, G., 2003. Separacio´n de aceitunas sobremaduras y alambradas en lınea mediante rebote (Segregating over-ripe and fish-eyed ('alambradas') olives on-line by means of rebound). In: II Congreso Nacional de Agroingenieria, Cordoba, Spain.
2. Consiglio Oleicolo Internazionale (COI/OT/NC n. 1 Dicembre 2004).
3. Diaz, R., Faus, G., Blasco, M., Blasco, J., Molto´ , E., 2000. The application of a fast algorithm for the classification of olives by machine vision. Food Research International 33, 305–309.
4. Diaz, R., Gil, L., Serrano, C., Blasco, M., Molto´ , E., Blasco, J., 2004. Comparison of three algorithms in the classification of table olives by means of computer vision. Journal of Food Engineering 61 (I), 101–107.
5. FAO, 1987. Norma del CODEX para las aceitunas de mesa. CODEX alimentarious CODEX STAN 66-1981, (Rev. 1-1987), 1-19.
6. Mateos, F., Patin˜o, A., Pe´rez, J., Tombs, J., Aguirre, M.A., 2005. Implementacion en FPGA de un sistema de procesamiento en tiempo real para la deteccio´n de defectos en frutos/the implementation in FPGA of a real-time processing system for the detection of defects on fruit. In: V Jornadas de Computacion Reconfigurable y Aplicaciones (Jcra 2005, pp. 151–157). Granada, Spain.
7. Mohsenin N. N., (l970). Physical properties of plant and animal materials. New York: Gordon and Breach Science Publishers.
8. USDA, 1967. United States Standards for Grades of Green Olives. United States Department of Agriculture Washington, Federal Register. August 9, 1967 (32 FR 11467).

Table 4. Samples collected, velocity and thickness of protection, number of drupes per kg and percentage of fruits suitable for processing in the samples collected.

Samples	**Velocity**	**Thickness**	**Total fruits Average (1st and 2nd test)**	**Healthy fruits Average (1st and 2nd test)**
	(rpm x 10^3)	(mm)	**no.**	**(%)**
1	2	7	876	76.7
2	2	19	912	52.7
3	2	7	822	66.3
4	4	19	912	68.6
5	3	14	1077	70.5
6	3	14	806	47.1
7	4	7	967	54.4
8	2	19	970	86.8
9	2	7	794	66.3
10	4	19	822	54.2
11	3	14	761	79.2
12	3	14	910	76.7

Table 5. Rotation velocity, thickness, type and percentage of damage produced in the operating conditions and with the teeth used during the harvesting of table olives.

Test	**Tooth rotation velocity (rpm x 10^3)**	**Thickness of protetion of teeth (mm)**	**Healthy drupes (%)**	**Damage**				
				biologic	**rubbing**	**Impact against box (wound) (unsuitable for processing) (a)**	**Impact against teeth (oxidation) (unsuitable for processing) (b)**	**Damage on the drupes unsuitable for processing (excessive oxidation + wound) (a + b)**
				(%)	**(%)**	**(%)**	**(%)**	**(%)**
1	2	7	76.7	3.2	10.4	0.8	8.9	9.7
2	2	19	52.7	1.1	21.1	1.7	20.0	21.7
3	2	7	66.3	3.5	12.3	1.0	17.1	18.0
4	4	19	68.6	1.4	16.6	1.2	12.1	13.3
5	3	14	70.5	0.6	20.7	2.5	5.8	8.2
6	3	14	47.1	1.9	37.6	3.3	10.0	13.3
7	4	7	54.4	3.4	28.4	1.0	15.5	16.5
8	2	19	86.8	1.6	6.9	0.3	3.5	3.8
9	2	7	66.3	3.5	12.3	1.0	17.1	18.0
10	4	19	54.2	0.8	27.6	3.6	13.9	17.4
11	3	14	79.2	0.4	11.2	1.1	8.8	9.9
12	3	14	76.7	3.0	11.0	1.6	7.9	9.0

Machines for Canopy Restraining in the Super Intensive Olive Growing [2]

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Abstract
This paper concerns long-term observations regarding the mechanization of the operation of the canopy restraining carried out on some super intensive olive groves of unlike age and different varieties (FS17, Arbequina, Arbosana), in order to supply an up-to-date information of the solutions adopted in Apulia.
According to the surveys executed in the tested super intensive olive groves, the mechanical restraining of the canopy has to be made as from the 4th year from the planting. The practicability of the different interventions through machines results different, in relation to: a) the particular carried out operation, b) the frequency of execution during the years, c) the consequent agronomic spin off.

Keyword: super intensive olive growing, mechanization, pruning

Introduction

The super intensive olive growing mechanization does not concern just the harvesting but above all the pruning and, in more general terms, the canopy restraining during the years until reaching the moment of the plant replacement. The costs of such operations, according to some experiences conducted in Spain, can represent up to 70% of the total cost of the ordinary management of the olive grove.
This paper concerns long-term observations regarding the mechanization of the operation of the canopy restraining carried out in some super intensive olive groves of unlike age and different varieties (FS17, Arbequina, Arbosana), in order to supply an up-to-date information of the solutions adopted in Apulia.
The problems concerning the mechanization of the pruning interventions arise from the necessity to harmonize two conflicting requirements: respect for the productive branches and, at the same time, the restraining of the section of the canopy, crosswise to the direction of the row, within compatible limits (height, thickness, form) with the sizes of the tunnels of harvest. These vary in the different harvesting machines, and for each one, with the adjustments.
The pruning interventions, carried out mechanically (topping, hedging and at the bottom of the canopy) and manually (up to the 3rd year from the planting) for the cutting of the branches placed below of the olives intercepting members (scales, buckets) of the straddle harvesters, still pay for a set of unreliability concerning the manner and the frequency of execution, in relation to: a) the age of the plant; b) the behavior of the variety; c) the cultivation techniques; d) the areale of cultivation.
The mechanization of some of such interventions (topping, hedging) are made with machines risen from the disk pruners for a time employed in traditional fruit and olive growing

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[2] *Each of the authors contributed in equal parts to this work.*

(Fontanazza *et al.*, 1998; Napoliello, 2000; Pascuzzi *et al.*, 2007; Tombesi *et al.*, 2007; Vega, 2004).

Materials and Methods

Technical solutions, craft made some of these, have been experimented for interventions of topping and cuts of raising of the bottom of the canopy (Figure 1). The tests have been carried out with a machine risen from the disk pruners for a time employed in traditional fruit and olive growing: «BMV» with 5 disk mounted on the straddle tractor «BRAUD» SB56.

Figure 1. Pruners employed for interventions of topping at height 2,20 m from the ground in an olive grove of the FS 17 variety (7th year from the planting) : [A]- pruner rised by «BMV» with 5 disk; [B] straddle tractor «BRAUD» SB56; [C] mowing bar; [D] mowing bar mounted on the tractor.

The surveys have concerned the evaluation of: a) the number of the pruning interventions, b) the operative velocities, c) the time of work/hectare.

The finishing touch has been carried out by means manual shears on the sides of the row; then the single side delivery raking has been made. Finally, the shredding pruning waste has been executed by means the shredder «FACMA» TR180PE (Fig. 2).

Results and discussion

The interventions of topping in olive groves of different variety and age have obviously

required very different operational velocities (from 0,2 to 3 km/h) and therefore times of work/hectare.
For the variety Arbosana, four years old, requiring, on average, four interventions of pruning for plant on branches having, almost all, diameter lower than 15 mm (Figure 3A), it has been enough more than 1 h-machine/ha, against the 23 h-machine/ha of the FS17, necessary (Table 1) to carry out on average 26 interventions of pruning for plant on branches having for 50% caliber higher than 15 mm (Figure 3B).
The subsequent operations, when expected: a) bottom lopping and manual finishing touch of the canopy, b) single side delivery raking, c) shredding pruning waste, have required unit employments of machines and manpower increasing with the age of the olive-groves.
Particularly: interventions concerning the restraining of the canopy have been not executed till 3 years from the planting; the cutting off the trunk of the branches placed further down has been made only at the 3th year from the planting; the intervention of topping has been necessary since the 4th year on, followed by the manual finishing touch of the canopy on the two sides of the row and from the mechanical shredding of the pruning waste.

Figure 2. Subsequent interventions of the mechanical top and bottom (of the canopy) lopping: [A] shortening or removal of the protruding branches in the inter-row, [B] cleaning of the under-canopy by the pruning waste, [C] single side delivery raking, [D] shredding.

The highest employments of machines and manpower, respectively lower than 25 h-machine/ha and 50 h-worker/ha have been reported in the seven years old super-intensive olive-grove of the variety FS17 for the operations: harvesting, canopy restraining and pruning waste. But here there are been the first serious problems with regard to the canopy restraining within sizes compatible with those of the tunnel of the harvester, to the point that to suggest a drastic reduction of the canopy to the wooden axis only. This has shown that the problems arise to impose the super intensive model of olive growing itself – over the reflections owing to the inexperience – are to investigate mostly from the agronomic side rather than the so called economic one.

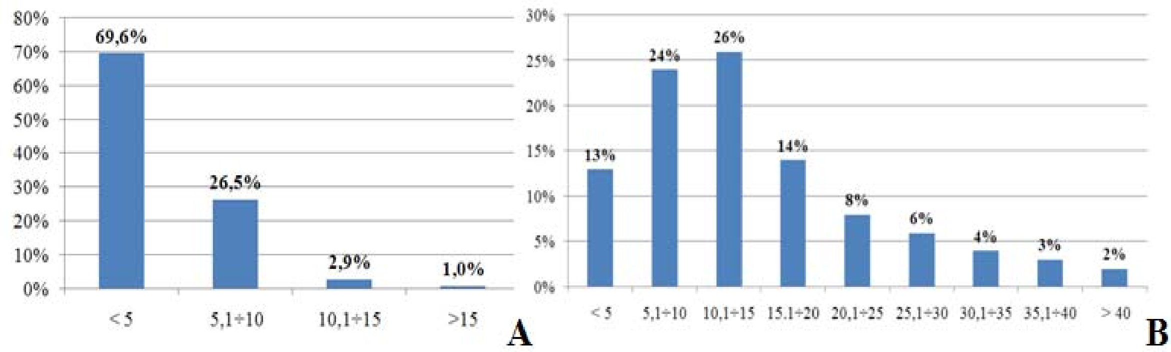

Figure 3. Average percentage values of the cutting number, by dimensional class partition, recorded during the last mechanical pruning intervention (topping) carried out in super intensive olive groves of the variety : A – Arbosana, B – FS17.

Table 1. Unit employments of machines and manpower.

Cultivar	FS17		Arbosana		Arbequina	
	A(1)	B(1)	A	B	A	B
harvesting(2)	6,1	12,2	2,8	5,6	1,4	2,8
topping	10,1	10,1	1,0	1,0	/	/
lopping of canopy bottom	3,1	3,1	/	/	/	9,6(3)
manual finishing touch and single side delivery raking of the branches	/	14,7	/	10,9	/	/
shredding of the branches	3,7	3,7	1,3	1,3	/	/
total	23,0	43,8	5,1	18,8	1,4	12,4
years from the planting	7		4		3	

(1) A : h-machine/ha B : h-worker/ha
(2) The unit employments are reported to the total time of work, including also the times of turning and maneuvering, of unloading of the picked product and possible cleaning of the tunnel of harvest with removal of the broken branches during the operation (variety FS17).
(3) A manual intervention of removal of branches placed at the base of the trunk was needed ever since 3 years from the planting.

Conclusions

According to the surveys executed in the tested super intensive olive groves, the mechanical restraining of the canopy has to be made as from the 4th year from the planting. The practicability of the different interventions through machines results different, in relation to: a) the particular carried out operation, b) the frequency of execution during the years, c) the consequent agronomic spin off.

The operations of topping, of raising of the bottom of the canopy and field shredding of the pruning waste, have not caused problems of particular importance, from the point of view of the employed machines. The greatest doubts have concerned, instead, the mechanization of the operations of hedging.
As a subsequent, even if swift, intervention of manual finishing touch on the sides of the row is anyhow necessary, the choice of some olive growers to totally exclude the employment of machines, for the execution of the operation, is justified.

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References

Fontanazza G., Camerini F., Bartolozzi F. 1998. Intervento meccanico e manuale nella potatura di produzione (Mechanical and manual intervention for the production pruning). Olivo e Olio, 1, 27-34.

Napoliello A., 2000. La potatura dell'olivo in Campania verso la meccanizzazione (The pruning of the olive tree towards the mechanization in Campania). Olivo e Olio, 4, 36-38.

Olint Redaction. 2006. Nouvelle machine débrousailleuse, 10, 18-19.

Pascuzzi S., Toscano P., Guarella A. 2007. La meccanizzazione della potatura di riforma degli oliveti (The mechanized pruning for restructuring of the olive groves). Proceedings AIIA National Congress Pisa – Volterra (Italy), 05-07 September 2007, 3, 77-80.

Pastor Muñoz-Cobo M., Humanes Guillén J., 2005. Poda de olivo: moderna olivicoltura. Editorial Agricola Española S.A., 142-212.

Tombesi A, Guarella P., Di Vaio C., Toscano P. 2007. Innovazioni nella meccanizzazione della raccolta e della potatura e ristrutturazione degli impianti olivicoli (Innovations of the harvesting and pruning mechanization and the reorganization of the olive plants). Proceedings International Congress «Research and Innovation of the olive and olive–oil chain production of the Mediterranean Countries», Bari (Italy) 18-20 October 2007, 175-190.

Vega Macía V., 2004. Poda mecanica del olivar, curso sobre olivar y sus derivados. Universidad de Castilla-La Mancha (unpublished), 326-332.

Intervention Methodologies to Enhance Sicilian Rural Coastline Landscape Within Climate Change

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Abstract
Nowadays with climatic change, global warming and desertification needing urgent attention and concrete responses, rational use of the planet's resources and safeguarding the global ecosystem are essential presuppositions for sustainable development together with economic prosperity and balanced social quality.
It is well known that these tensions are most exacerbated in strongly anthropic areas like those of the agro-Sicilian coastline. In most of these areas, extensive overbuilding due to urban, industrial and tourism sprawl, and intensive agriculture have above all impoverished the coastline, depleted typical Mediterranean vegetation, eroded the soil, and therefore modified the environment. This work proposes to analyse parts of the Sicilian agricultural landscape, in Ragusa territory, to acquire data on the factors determining the evolution of this degradation and develop intervention methodologies within climate change.

Keywords: rural landscape, climate change

1. Introduction: Climate change, desertification and their impact on the Sicilian coastal landscape.

The Mediterranean basin is already over exposed not only to meteorological extremes (flooding and droughts) but also to natural ones (earthquakes, geological and hydrological instability etc.) due both to the complexity of the environmental, anthropological, social and infrastructural systems as well as to the peculiar characteristics of its ecosystem and its historical, artistic and cultural heritage.
The current and anticipated climatic trends impacting the territory and its landscape are further exacerbated by other factors linked to overexploitation and the unsustainable management of ground resources like crop practices, animal breeding and the management of water resources.
The concept of desertification increasingly relies on environmental and human interaction covering all phenomena of 'soil erosion in arid, semi-arid and sub-humid dry areas, attributable to various causes amongst which climate change and human activity'. This definition, adopted by the United Nations Convention for the Fight Against Drought and Desertification (UN CCD) defines its scope as a function of climatic characteristics and introduces some innovative key concepts: the causes may be both natural and human; erosion is not only the loss of physical and biological characteristics, but also the loss of profitability; the arid, semi-arid and sub-humid dry areas are the most vulnerable in the world requiring urgent intervention.

The environmental and socio-economic peculiarities shared by Sicily and other Mediterranean countries apart from the semi-arid and sub-humid dry climate, seasonal drought, huge rainfall variations and sudden violent downfalls, are the poor soils susceptible to erosion, the heterogeneous landmasses with steep slopes, a crisis in traditional agriculture characterised by the abandonment of the countryside and deterioration in the protection of soil and water, the unsustainable overuse of water resources, and finally the concentration of economic activity along the coasts as well as increasing urbanisation, industrialisation and tourism.
In the Region (Schifani, 2003) and provinces of Ragusa, Siracusa, Agrigento and Catania as confirmed by a CTM (The Mediterranean Remote Sensing Centre) study (1999), desertification is caused by: the abandonment of the countryside, the replacement of traditional farming techniques by modern ones; the irrational management of grazing; the introduction of non-indigenous forest species; the impact of tourism, urban expansion and the transportation infrastructure; poor water management.
According to some data (Salvati et alt., 2005), almost the whole of Sicily - 94.4% - is at risk of desertification on the basis of meteorological data for 1971 – 2000 (fig. 1).

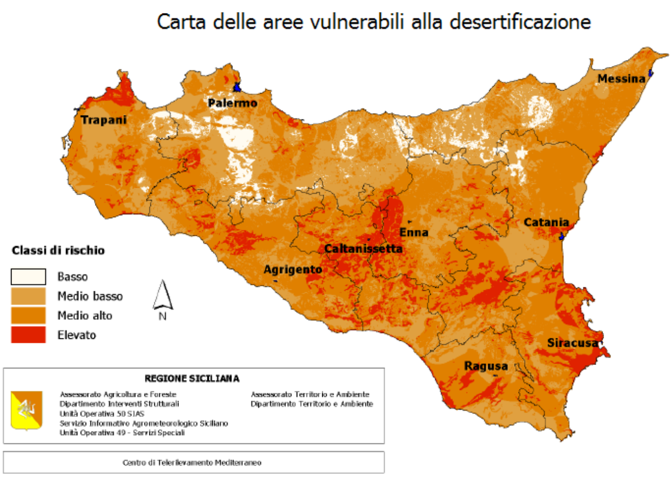


Figure 1. Map of areas vulnerable to desertification in Sicily (Drago, 2003)

2. Aim and method

In the above description, the areas investigated are on the Sicilian coast showing considerable evidence of desertification: the greenhouse area of the Ragusa coast. In particular, the Macconi area (fig. 2) is almost totally covered by greenhouses as far as the final coastal strip which was once of imposing dunes but is now a narrow sandy shore being eroded.
Guide lines for re-designating the landscape have been proposed to promote actions which counteract the current tendency by re-introducing tourism which respects a functional and ecological equilibrium as well as the natural identity of place.

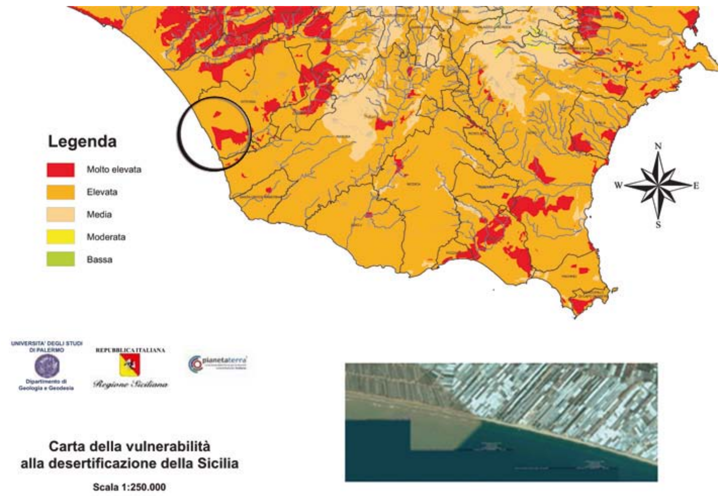


Figure 2. Study zone

By detailed analysis of the landscape, environmental and anthropic systems, the research aims at providing support for planning and designing the Ragusa coast in light of climate change and the consequent desertification.

Intervention requires good knowledge of the area and its potential as well as any current conflicts. With this aim, a methodology was developed over three different phases (fig. 3):

1. analysis: substantial analysis which summarises territorial characteristics, their interrelations, their historical evolution and the evolutionary, structural and perceptive dynamics of the landscape;
2. processing: based on studying man-environment conflicts, the interferences between anthropic activities and natural processes; on defining territory specific sensitivity/vulnerability indicators; on processing explanatory summaries
3. proposal: guidelines produced by applying a case study which describe the means to safeguard and plan landscape in similar environments.

3. Results and discussion

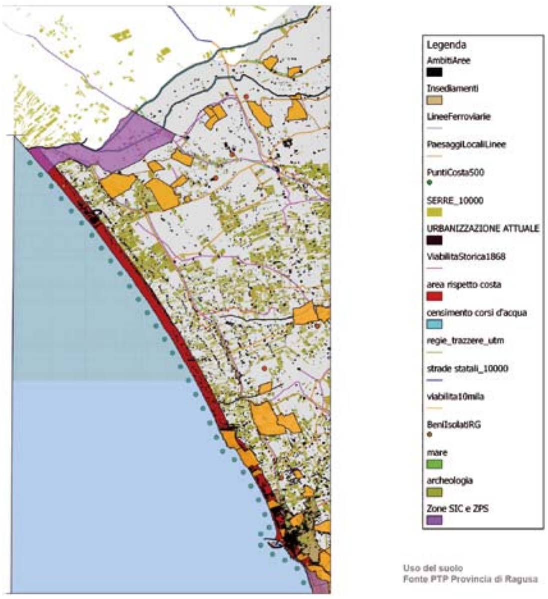
3.1 Knowing the territory

Landscape analysis should be based on a global vision of all the processes involved from natural phenomena to the relationship between man and his environment. The variety and heterogeneity of the information and the numerous themed maps make the overall analysis quite complex so a structured program is needed to understand ongoing developments and the possible evolution of the landscape which should embody the investigations carried out as well as integrate the evaluations.

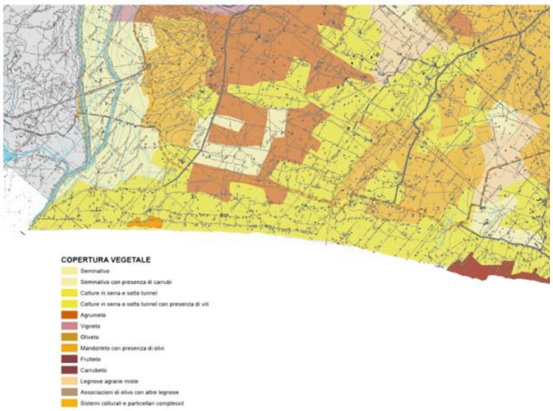
The analytical process can be broken down into:

- Landscape analysis which forms the knowledge base for design/management.
- Environmental component analysis as it links to climate change which provides a specialised knowledge base on the landscape and its health.

To help with the investigation we analysed historical maps (IGM), Territorial Plan maps and the Territorial Landscape maps of Ragusa Province to fill out the physical, environmental and anthropic characteristics of the territory (fig. 4) and its intended applications while taking into account the provisions of urban planning.



Uso del suolo – Fonte PTP Ragusa



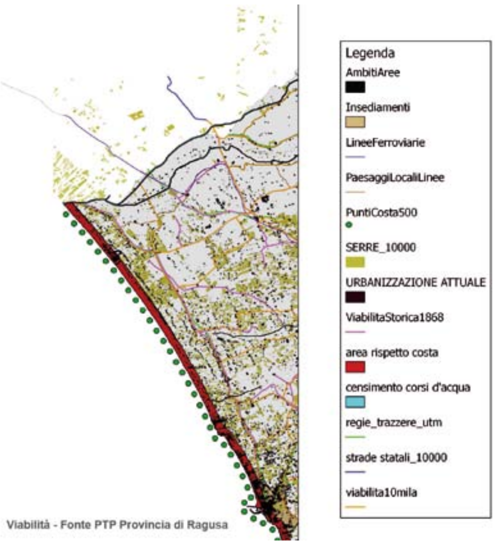


Figure 4. *Place analysis and key*

Providing the means to better understand the environmental components of a territory and to evaluate more precisely its vulnerability to desertification, given that these are the most important aspects governing the best management or resources, a methodology was created using collected and already validated data to highlight all the issues relating to desertification.

tab. 1. Desertification & loss of landscape potential	**Study criteria**	**Vulnerability criteria**	**Problem**
	Environment /Man conflict Interference between Man and natural processes	Natural causes	Areas: Sensitive Vulnerabile At risk Already subjected
		Anthropic causes	

This led to cataloguing the areas into Sensitive, Vulnerable, At Risk and Already Subject To (tab. 1) in which the combined aspects of climate, vegetation, soil and socio-economics help measure the state of resources and the human pressures at work. In the next phase, specific indicators to monitor the phenomenon were set up as well as appropriate instruments and techniques (guidelines) for managing the territory. The landscape was evaluated to prefigure it to one or two scenarios as defined by policy for the landscape and environment. The scenarios represent a balance between criticality/complexity and landscape potential/opportunity (tab. 2) taking into account future risk in relation to landscape characteristics and highlighting any 'sensitive' areas, any pressure factors and 'vulnerabilities' (Riguccio et al., 2008).

tab. 2. Evaluation

Study criteria	Parameters
Critical state	Degree of human intervention and/or transformation
	Risk identification
Potential	Attitudes to conservation & identifying values
	Compatible uses

3.2 Defining parameters/indicators for desertification and applying them to the case study.

Territorial degradation is therefore linked to alterations in soil-water-vegetation factors and only by analysing all the data and information regarding them can they be monitored and quantified.
By referring to the main anthropic activities in the territory, the study has revealed several indicators which highlight conflicts with the environment and interference between human and natural processes. This interference can provoke physical, chemical and biological alterations.
The indicators have been subdivided into **activity sectors** (Agriculture, Tourism, Urbanisation, Infrastructure). To standardise the information with the data obtained from the landscape analysis these indicators have been subdivided according to vulnerability into: **structural, functional** and **perceived** (Russo e Riguccio, 2009).

<u>The indicators' estimate</u>
The indicators provide information which is combined with qualitative evaluations of the specific territorial context. They help in evaluating the potential/criticality of the territory and in identifying strategies for sustainable development. Each indicator (Riguccio et al., 2009) is able to carry out a 'prompt evaluation' of territorial vulnerability by attributing a specific value and verifying the actual trend (Tab. 3) (DiSGAM, ARPA, 2003).
So, by way of a subjective evaluation, values were attributed to those indicators on the basis of statistical data and territorial interpretation. The results were further catalogued according to a value (Vulnerability Index VL), calculated by a method developed in the

Table 3. Vulnerability index

Value	Very low	Low	Moderate	High	Very high
Brief evaluation					
Variable V^n	1	2	3	4	5
Actual tendency					

trend	^ improvement	= stable	v worsening

previous phase which sets the 'risk category' which in descending order identifies territorial intervention priorities (tab. 5) (Riguccio et Alt., 2009). The risk value was quickly chosen from table 4 (DiSGAM, ARPA, 2003).

Table 4. RISK CATEGORY					
Risk	*Very low*	*Low*	*Moderate*	*High*	*Very high*
Variable R	*≤ 5*	*5≤R≥10*	*10≤R≥15*	*15≤R≥20*	*≥20*

4. Adaptation and intervention strategies: setting up guidelines and identifying compatible utilisation.

The intervention strategies put forward by the IPCC (Intergovernmental Panel on Climate Change) can be condensed into two key terms: mitigating *global climate change* and adaptation. Adequate intervention as expressed by the IPCC might lead to significant results; intervention strategies should not be backward looking but anticipate the expected changes over the next 30 – 40 years.

Mitigation means human intervention to reduce greenhouse gas sources or increase removal processes whereas adaptation means adjusting natural or human systems to environmental change either for damage limitation or to exploit opportunities.

Adaptation to the impact of climate change is a complex process implying adjustments in time and space in response to expected or ongoing climatic variations. Adaptation involves both natural and socio-economic systems both of which can be 'autonomous' (ie. spontaneous responses to change mostly by ecosystems in natural systems and by the private sector in socio-economic ones) or 'planned'.

The National Action Programme (PAN) in the Fight Against Drought and Desertification passed by CIPE no. 229 (21/12/1999), provides for a complementary setoff interventions in the following priority sectors: protecting the land, sustainable management of water resources, reducing the impact of manufacturing, re-establishing territorial equilibrium (eg. recouping degraded soils, land reclamation and re-naturalisation etc.).

On the basis of these indicators for reducing the impact of climate change it is necessary to rediscover closer ties to nature with a high capacity for adaptation and re-establishing the equilibrium in both urban and rural areas.

In light of the coastal area analysis by activity sector (Agriculture, Tourism, Urbanisation, Infrastructure), a 'good practice' outline has been drafted setting out strategies to set in motion the regeneration of the coastal landscape (fig. 5). Fine-tuning the guidelines was helped by territorial planning and programming apparatus which identify specific fundamental objectives: accessing the sea, safeguarding dunes, cycle/walk paths, landscape mitigation and improvement, mitigating impact on land and water, diversifying sector economics (greenhouse crops), farm multi-functionality and increasing facilities and services for tourism.

Table 5. SUMMARY OF GUIDELINES FOR THE 'MACCONI' COASTLINE & INTERVENTION PRIORITY BY RISK INDEX

VL	I	R	GUIDE LINE
1		≤ 5	
2	AF^1,AF^2,TF^6, US^5,US^3	$5 \leq R \geq 10$	Diversification of tourism; tourism flow management.
3	AS^1,AS^2 AS^3 AS^8 AS^9 AF^5 AP^1 AP^2 AP^3 TS^1 TS^2 TS^3 TS^4 TS^6 TF^1 TF^2 TF^7 TP^1 TP^2 TP^4 US^1 US^2 US^4 UF^2 UF^3 UF^6 UP^1 UP^2 UP^3 UP^4 IP^1 IS^1 IS^2 IS^3 IF^1 IF^2 IF^3 IF^4	$10 \leq R \geq 15$	Recovery and re-use of organic fractions as fertiliser; de-seasonalising demand; creation of green spaces and parks to re-grade the environment and improve micro-climates; restore residential and agricultural buildings; re-vitalise waterfronts; functional re-grading of public spaces; improving public transport to disincentivise private transport; reconfiguration and reorganisation of access systems; creation and promotion of an alternative road network; tourist flow management; up-grading rainwater drainage; improving the roadside view of the countryside.
4	AS^5 AS^6 AS^7 AF^3 AF^6 AP^4 AP^5 TS^5 TS^7 TF^5 TF^8 UF^1 UF^5 IF^5 IP^2	$15 \leq R \geq 20$	Re-naturalisation of water courses; multi-functionality of rural spaces (holiday farms, agricultural parks, educational farms, agricultural museums etc.); creation of ecological networks; promoting quality brands; sustainable use of water resources; use of low saline water and adopting techniques for mixing water of varying salinity; incentivising traditional agriculture; promoting cultural tourism; diversifying demand; incentivising rural tourism; improving the efficiency of the water network and using renewable energy sources; sustainable management of solid urban waste; incentivising slow mobility.
5	AF^4 TF^3 TF^4 TP^3 UF^4 IP^3	≥ 20	Recovery of marginal areas; recovery of the dune coastal strip; re-naturalisation of abandoned agricultural land; reduction in the consumption of natural soils and the adoption of agricultural good practices; protection and amelioration of cultural and landscape features; reduction in rainproofed areas; research into alternative sources for water provision; improvement in collection, cleaning and disposal of urban waste; optimisation of the existing road network; incentives for public transport.

A: Agro-silvo-pastorale; T: turismo; U: urbanizzazione; I: infrastrutturizzazione; S: vulnerabilità strutturale; F: vulnerabilità funzionale; P: vulnerabilità percettiva (fonti: URI, Assessorato Agricoltura, APAT, ARPA, Osservatorio nazionale rifiuti, piani paesistici, piani territoriali, PRG). L'apice corrisponde all'indicatore specifico riportato in Riguccio et Alt., 2009.

Table 5 – Table 5. Guideline summary for the 'Macconi' coast and intervention priority by risk index.

5. Conclusions

The results of the study lead to drawing some conclusions. Today's Macconi system, and in general the Ragusa coast, is undergoing huge pressure from agriculture and urbanisation as highlighted by the VL values and which represent medium high risk factors. Therefore, short-term intervention is required through re-grading and by creating new scenarios which introduce techniques of adaptation to current climate change. These interventions, described in the guidelines, should be capable of augmenting landscape/environment quality as well as the identity of place and also capable of initiating territorial development processes which, for Sicily, would be linked to the tourism and agriculture sectors.

	Landscape Strategies	Description	Eìxamples & suggestions
AGRICULTURAL SYSTEM	Agricultural park.. Museum agriculture. Educational Farms. Rivitalising rural space.	Open-air museum path circuit tracing the evolution of agricultural practices Re-acquisition of abandoned agricultural land and greenhouses put out of business by tourism or other means.	 
ANTHROPIC SYSTEM	Public space. Accessibility. Slow mobility. Waterfronts.	System of places and inter-connections which by exploiting historical thoroughfares, emarginated and abandoned areas and the existing micro-network creates: access to the sea and viceversa, a cycle-path network which connects the coast with its hinterland, ways of crossing the dunes, tourism facilities.	 
ENVIRONMENTAL SYSTEM	Restoring ecology-environment equilibrium. Re-grading water courses.	Re-establishing the environmental conditions of the Dirillo estuary, starting up environmental tourism, reintroduction of traditional cultivation, creation of a 'green ecological biway' within the landscape.	 

Figure 5. Strategies and intervention suggestions

BIBLIOGRAFIA ESSENZIALE

- AA.VV. 2007. Atlante Nazionale Delle Aree A Rischio Di Desertificazione Inea – Is. Nazionale Di Economia Agraria.
- AA.VV. 2007. Final part of the IPCC's Fourth Assessment Report (AR4), 'IPCC.
- Fusero P. Simonetti F. (a cura di). 2005. Piano territoriale della provincia di Ragusa.
- Schifani G. 2006. Problematiche e prospettive economiche del ruolo dell'agricoltura nella lotta alla desertificazione, ESAF.
- Riguccio L., Falanga C., Failla A., Tomaselli G. 2008. "Riqualificazione del paesaggio agro-urbano costiero: un caso studio per la città di Catania". Agribuisness Landscape & Environment Management
- Riguccio L., Falanga C., Tomaselli G., Failla A., 2009 "La riqualificazione paesaggistica del territorio agro-urbano-costiero ragusano nel contesto della desertificazione". IX Convegno Nazionale AIIA.
- Russo P., Riguccio L. 2009 "Metodologia di gestione sostenibile del Paesaggio Agro-UrbanoCostiero Mediterraneo. AISSA

Mechanical Pruning Tests and Economic Analysis in Spanish Intensive Olive Growing Systems

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Abstract
Modern olive cultivation development is closely connected to the mechanization of pruning operations which, together with harvesting, influence considerably olive-tree yields and productions quality. The objective of the present study is to assess performances, and economic aspects, of mechanized pruning operation in spanish intensive olive-groves. The intensive cultivation system (density of 250-600 trees/ha) is still very effective, and in order to make it more competitive, there is an increasing interest towards pruning interventions made using machines able to carry out both topping and hedging. Tests, carried out in Spain concern two different olive-groves cultivated in pots and in monocone. The technical results of this study will be used to carried out an economic analysis aims to assess the convenience of mechanical innovations in olive farm. The economic efficiency will be evaluated in terms of saving in labour, to investigate the economic validity of technological innovations in olive growing, based on the criteria of intensive fully mechanized cultivation. The obtained advantages through the employment of machines able to carry out topping and hedging, and speed pruning operations, are notable. Indeed, it is possible to prune a hectare of olive-grove in about one hour, as it is demonstrated by the working operating capacity brought out during the tests. The economical analysis carried out shows that the use of these machines is particularly interesting since it allows to effectuate a cultural intervention often neglected because of its high costs.

Keywords: mechanization, pruning operations, economic analysis

Introduction

The world olive growing situation presents a complicated outline, where the distinctive aspects concern the spreading of an olive growing characterized by high production costs and low productivity. Inside this scenery it is very important to support a process of modernization which can allow the passage from the traditional growing systems to others which involve a specialized and intensive olive cultivation, with a larger number of trees per hectare, a stronger use of modern agricultural techniques together with a higher level of mechanization.

During the 70s, consequently to the crisis of the traditional olive cultivation, which started in the half of the 50s with the rural emigration and become more marked in the 60s for the competition of other vegetable oils, the so-called "new olive-cultivation" started in Europe. The aim of this "intensive" new olive cultivation was to realize plantations fit for the mechanical harvest with trunk shaker, characterized by a precocious production and higher productivity. Spain was one of the first countries which adopted these modern cultivation techniques, by increasing planting densities of olive-groves with 500 plants/ha (Rallo *et al.*, 2006). At the beginning of the 90s, a new olive cultivation technique developed in Cataluña, with the use of the superintensive model allowed to have 2000 and over plants per hectare. This density was considered impossible, until then, for a centuries-old species as olive is; in fact it was employed only for apple and pear trees on dwarfing rootstock and for peach-trees afterwards (Loreti, 2007). While the superintensive model is spreading all over the world very quickly, although all the matters about its sustainability, the "intensive" cultivation system, with plants grown in pots and in more modern "single cone" forms is still very effective and, in order to make it more competitive, there is an increasing interest towards pruning interventions which can be made using machines able to carry out both topping and hedging (Lodolini *et al*., 2006).

In this work, carried out in Spain, are reported the results relative to the first year of mechanical pruning tests, carried out in intensive olive cultivation systems. The aim of this research was to evaluate the achieved performance and make a comparison in terms of productivity and quality with the previously done work. During the tests, operational time assessment was carried out according to the formalities provided for by C.I.O.S.T.A. classification.

Materials and methods

The tests, carried out in Spain (Reus) concern two different olive-groves: **Olive-grove A** cultivated in pots and **Olive-grove B** cultivated in single cone. Both systems, made up of thirteen-year-old "Arbequina" plants (selection Agromillora), present flat position, North-South direction and are provided with drop fertirrigation. The olive grove cultivated in pot has planting density of meter 4.50 x 3.50 (635 plants/ha), plants of 3.15 m high and crowns of 0.70 m from the ground; the single cone olive grove has a planting density of m 4.50 x 3.00 (741 plants/ha), plants of 3.20 m high and crowns of 0.90 m from the ground. The dimensional and technical characteristics of the tested areas are reported in table 1.

The work equipment is made up of the single worker operating the pruning machine. The beginning of each survey is the moment when the machine is in front of the row ready to start the pruning and the final point is when the work in the tested areas ends. In both olive-groves the intervention scheme, elaborated on a triennial base, envisages for the first year the cut of a single hedge along the rows to be carried out with a double passage of the machine.

The first passage provides a cut with an average inclination of 20-25° off the vertical and an average depth of about 0.70 m in the crown; the second passage provides a cut with an inclination of 10-15° off the horizontal. This scheme envisages the same intervention on the opposite hedge in the second year, while in the third year the topping, together with a manual final touch, is envisaged. The pruning machine employed, mounted towards the front on a 40 kW self-propelled fork-lift truck, is comprised of a series of two couples of sharp toothed wheels with a diameter of 0.60 m e 0.65 m, placed on the same supporting shaft (figure 1). These hydraulically operated wheels are made of tempered steel and have teeth in widia plates in order to facilitate the work; they have a rotation speed of 2.000-2.500 cycles/min and are able to cut branches with a diameter of over 8 cm without problems.

Table 1. Dimensional and technical characteristics of the tested areas.

Tested areas		**Olive Grove A**	**Olive Grove B**
Dimensional characteristics before pruning			
Elements	Measurement Unit	Value	
Plants height	[m]	3.15	3.20
Crown longest diameter	[m]	3.80	3.60
Crown shortest diameter	[m]	2.40	2.33
Crown volume	[m^3]	6.10	7.13
Avenue width	[m]	0.70	0.90
Dimensional characteristics after pruning			
Plants height	[m]	3.15	3.20
Crown longest diameter	[m]	3.15	3.05
Crown shortest diameter	[m]	2.40	2.33
Crown volume	[m^3]	4.83	4.27
Avenue width	[m]	1.35	1.45
Olive grove technical characteristics			
Age	[years]	13	13
Density	[p/ha]	635	741
Tested rows	[n]	4	4
Row average length	[m]	147	210
Plants per row	[n]	42	70
Work equipment	[n]	1	1

Figure 1. Pruning machine used during the tests

Results

Table 2 reports the data about working times collected during the first year of tests for both olive groves. These data show that the working operating time (TO) is, on the average, equal to 0.94 h/ha, the additional time (TA) is equal to 0.10 h/ha, while the dead time (TM) is equal to 0.35 h/ha.

Table 2. Collected data about times during mechanical pruning tests for both theses

Olive Grove	TE [h/ha]	TA [h/ha]	TO [h/ha]	TM [h/ha]	TU [h/ha]
A	0.77	0.10	0.87	0.40	1.03
B	0.97	0.10	1.01	0.30	1.39

Note:
TE = Effective time TA = Additional time TO = Operating time TM = Dead time TU = Usage time

These data about times demonstrate working productivity and efficiency whose values are reported in table 3, show that the average advance speed of the pruning machine along the rows is equal to 2.60 km/h; so the working capacity referred to the operating time is 1.12 ha/h for olive grove A and 0.94 ha/h for olive grove B.

Table 3. Data about working capacity and productivity collected during the tests

Taken away wood		Pruned branches diameter		Pruning machine advance speed	Working capacity	
		< 4 cm	> 4 cm		Referred to TO	
[kg/plant]	[t/ha]	%		[km/h]	[ha/h]	[t/h]
Olive grove A						
6.3	4.0	70	30	2.88	1.12	4.48
Olive grove B						
3.5	2.6	65	35	2.27	0.94	2.45

The quantity of taken away wood is equal to 6.3 kg/plant in olive grove A e 3.5 kg/plant in olive grove B, with an average value of 3.3 t/ha. The diameter of 68% of pruned branches is, on the average, shorter than 4 cm.

Economic analysis

In olive cultivations, pruning is the second demanding practice just after harvesting from an economic point of view, as it generally accounts for 20-40% of annual production costs, depending on its type and frequency (Lodolini *et al.*, 2006). Therefore, in order to reduce production costs, considering, the increasing of agricultural labour cost and the scarcity of skilled labour, it is necessary to apply mechanized techniques for pruning and harvesting (Gucci *et al.*, 2000).

According to statistical data available from the Spanish Department of Environment and Rural and Marine, in 2008, the national average wage by categories (euro/day) was represented by the following values: 50.10 euro/day for skilled labor and 35.60 euro/day for not skilled one. The present study carries out a comparative analysis between manual and mechanical pruning costs, considering data from both, literature (Fontanazza *et al.*, 1998; Pastor *et al.*, 2006; Sillari *et al.*, 1998; Zimbalatti *et al.*, 2009) and experimental tests. The cost of manual pruning effectuated by a labour constituted by three men using chainsaws represents a total amount of 177,7 €/ha. On the other side, mechanical pruning which was effectuated just by one operator driving the machine (tests A and B), and completed by a final manual touch, costed 79,44 €/ha (average of the two tests). In conclusion (table 4; figure 2), it can be affirmed that with mechanical pruning it is possible to economize approximately the 55,3% of pruning labour costs in olive cultivations.

Table 4. Data about working capacity and productivity collected during the tests

	Manual Pruning	**Test A**		**Test B**	
		Mechanical pruning A	*Manual final touch A*	*Mechanical pruning B*	*Manual final touch B*
Work rate (h/ha)	22.70	1.03	7.57	1.39	7.57
Pruning labour costs (€/h)	7.83	5.56	7.83	5.56	7.83
Pruning labour costs (€/ha)	177.7	5.73	59.25	7.73	59.25
Total labour costs (€/ha)	**177.7**	**17.19**	**59.25**	**23.20**	**59.25**

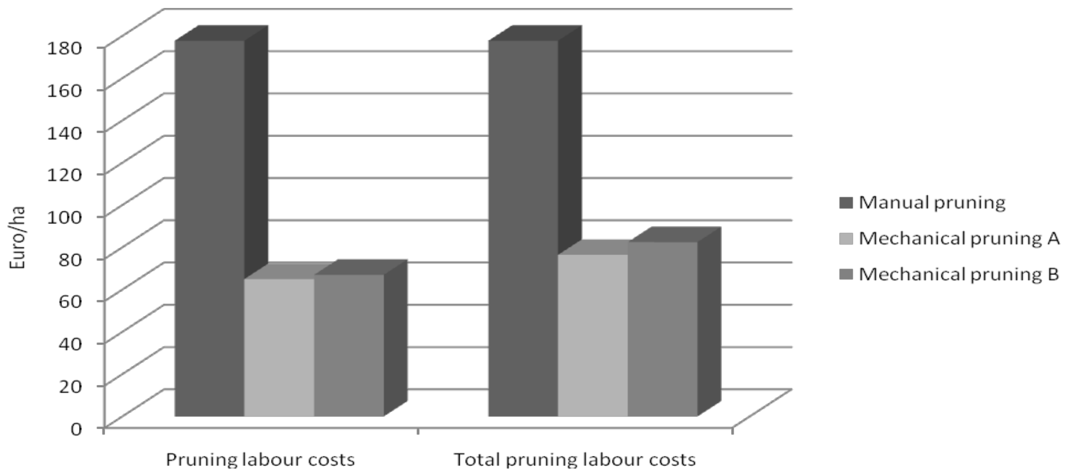

Figure 2. Comparison between pruning labour costs

Conclusions

Mechanical pruning employment in the intensive olive grove, besides cutting down the costs, it is reduced to a uniform cut of the tree-crown which can be carried out without particular problems (Giametta *et al.*, 1997). The cut efficiency of these machines is obvious, so that it is possible to prune a hectare of olive-grove in about an hour. This pruning system is particularly fit for single cone cultivations.

As concerns pot cultivations, for the different opening of branches, the machine operator could have some problems in case of drastic pruning, since he could inadvertently cut whole branches. This could undermine the tree structure and make manual pruning interventions necessary in order to restore the cultivation kind chosen. Moreover mechanical pruning is not selective, since useful and useless wood is removed; so a reduction of buds, with a consequent fall of production, can occur. However, since this is only the first year of experiments, final remarks about olive vegetative/productive aspects cannot be expressed, yet. All these indications can be available only after further, thorough studies. It is easy to foresee that the mechanization of pruning operations will be very successful in the future, since it is an effective solution to carry out this expensive, but important, cultivation practice.

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References

Sillari B., Cantini C., 1998. Risultati produttivi ed economici di oliveti condotti con diversi sistemi di potatura. Rivista di frutticoltura n. 1: 49-54.

Fontanazza G., Camerini F., Bartolozzi F. 1998. Intervento meccanico e manuale nella potatura di produzione, Olivo E Olio, 1.

Giametta G., Zimbalatti G. 1997. Mechanical pruning in new olive groves. Journal of Agricultural Engineering Research, 1, 15-20.

Gucci R, Cantini C. (2000). Pruning and Training Systems for Modern Olive Growing. CSIRO Publishing, Australia.

Lodolini, E.M. 2006. Per una potatura razionale, economica e secondo natura. Olivo e Olio, 5, 12-18.

Lodolini E.M., Neri D., Caporossi F., Caporossi C. 2006. Potatura meccanica dell'olivo: meno costi, più produzione. L'informatore Agrario 38: 50-53.

Loreti, F. 2007. Alta densità: rivoluzione globale nelle tecniche di coltivazione dell'olivo. Rivista di Frutticoltura e Ortofloricoltura, (7/8), 56-70.

Ministerio de Agricultura, Pesca y Alimentación, 2008. Indicadores económicos del medio rural (precios). Salario Medio Nacional según categorías laborales. http://www.mapa.es/es/estadistica/infoestad.html

Pastor Muñoz-Cobo M., Humanes Guillén J. 2006. Poda del olivo. Moderna olivicultura. 5ª edizione, ed. Agrícola española s.a., 127-138.

Rallo L., De La Rosa R., León L., Guerrero N., and Barranco D. 2006. L'olivicoltura intensiva in Spagna. Seminario internazionale su: "Innovazione tecnologica in olivicoltura tra esigenze di qualità e di tutela ambientale", Cittanova (RC), 11 settembre, 21-25.

Zimbalatti G., Bernardi B., 2009. Manual and mechanical pruning tests in the super intensive olive growing. Olivebioteq, Third International Seminar "For a renovated profitable and competitive Mediterranean olive growing sector". 15-19 December 2009, Sfax, Tunisia.

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