USE OF SUSTAINABLE TECHNOLOGIES IN AGRICULTURE

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CONCEPT: Energy Balanced Assessment in the development **of Software** for mission planning and control semi-autonomous agricultural vehicles (tractors and supporting units) that already exist. The service combines ICT (Information and Communication Technology) with satellite- based navigation (GNSS).

The System Software consists of the following elements:

- Path-Optimization Algorithms
- Mission-Planning Strategy
- User Interface

The Software can be applied in computer – control precision farming in conjunction **with existing vehicles**, redesigned for semi autonomous operation (tractors, trucks, etc).

The farm machinery guidance system is composed of two parts: the hardware components and the software which directs the hardware to execute any command or instruction. Hardware components are constructed by outsourcing suppliers. They whole system is distributed by our company and is sold to end users-costumers, which could be farmers and farming industries. Our product is a service (software, hardware) offered by a company of the privet sector.

Elements out of the boundaries of our project - Tractors Physical Hardware:

- Actuators
- Sensors
- Vehicle Electronics

Using satellite technology, user assigned field tasks are performed using optimized intelligent path (implementation of B-patterns, for the optimal planning of field area coverage) and mission planning.

AIM: The development of a service that can be applied in optimally manage traditional field operations like:
–Planting
–Spraying
–Harvesting
- Fertilizing
-Disc-harrowing
-Irrigation
–Spraying Spot Chemical Application

Satellite technology and augmentation systems (GVC), are going to be used in order to improve agriculture productivity. Satellite tracking, ploughing monitoring, harvesting, distribution of fertilizer, herbicide and water irrigation are some of the applications of positioning technologies that can be incorporated in our technology. The technology has been tested in several countries, giving to the end users important economic and environmental benefits.

An overview of the proposed system (*Intelligent Technologies for Future Farming DaNet Thematic Workshop Horsens, Denmark, 27 March 2003) can be seen in the following Fig.1*

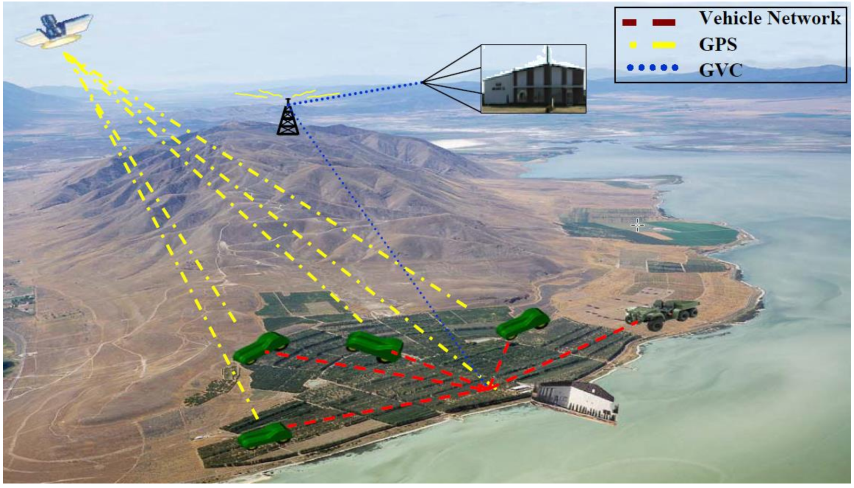


Fig 1. Overview of the proposed system

GNSS augmentation system (GVC): Augmentation systems are used to increase the accuracy of the basic GNSS signals, by transmitting corrections to the GNSS receivers either via satellite or terrestrial radio. For instance, instead of a normal GPS accuracy of 4, 5 m, an augmented system can pinpoint this location measure to an accuracy of 0, 6 m (Ikokou Blanchard G, 2013).

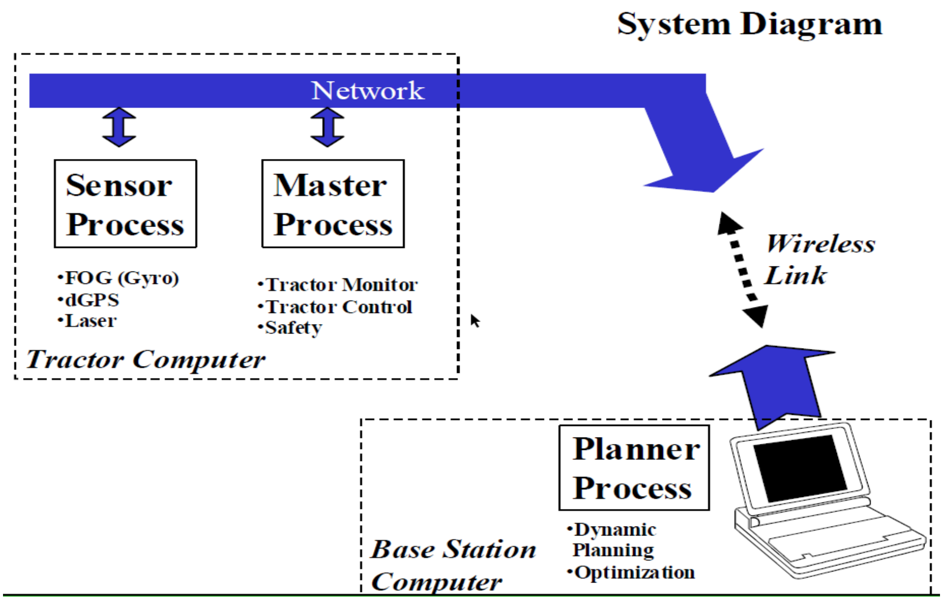


Fig.2 System diagram

Materials and use: This kind of technology requires the optimum implementation of sensors, actuators and computers (e.g. laptops) in the so called intelligent vehicles. The hardware basically consists of four key groups of sensors that perform the following tasks (**Francisco Rovira-Más**, 2010)

- local perception and vicinity monitoring
- global positioning
- attitude and control
- non visual tracking of production parameters

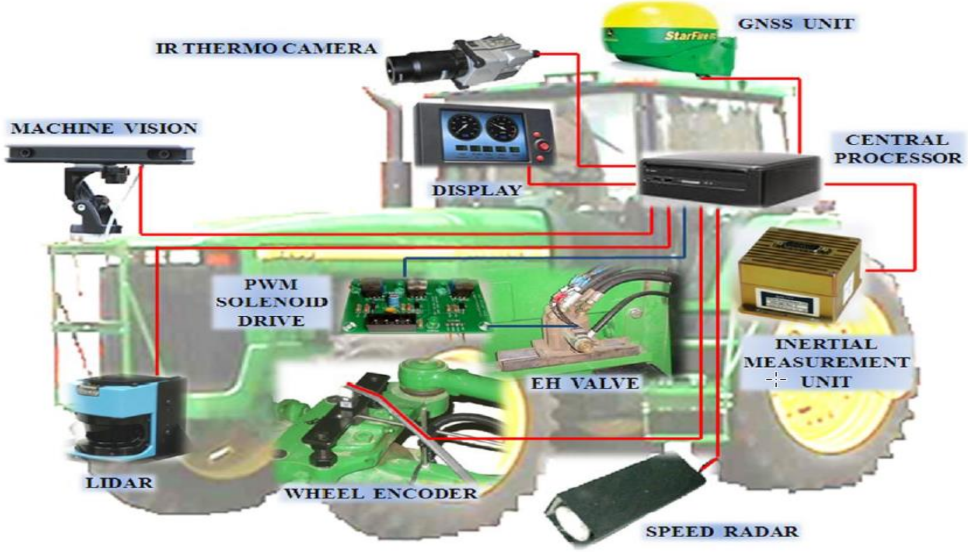


*Fig 3***:** A case of a generic network for an intelligent agricultural vehicle.

Hardware is distributed by our company with the software and is sold to end users-costumers, which could be farmers and farming industries, conductors maintaining or providing the system.
Specification of the products, installation and possible maintenance activities is performed by our company. These includes the as assemblance of the hardware and the installation of the guidance Software. Maintenance includes update features of the guidance software and the replacement or service of faulty products.

Possible applications are:

- Agricultural vehicle guidance – this technique reduces skips and overlaps, lower operator fatigue and enhances the ability to work in poor visibility conditions. Offers the ability to accurately follow particular traffic patterns and provide feedback for appropriate respond (Ikokou Blanchard G, 2013).

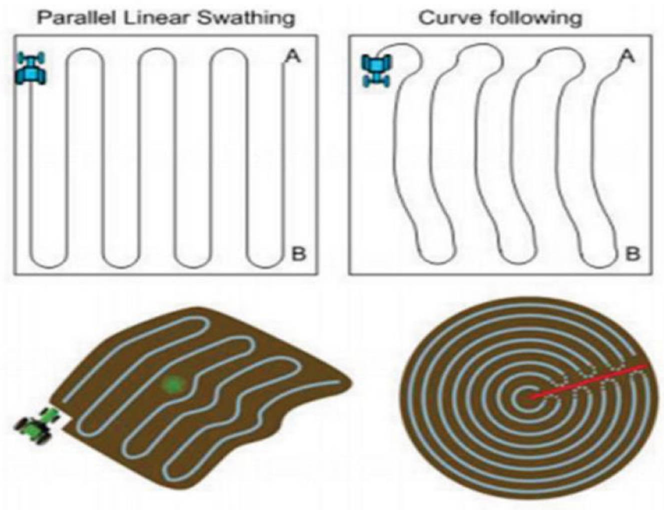


Fig 4: Examples of field traffic patterns that a vehicle equipped with GNSS can follow

Execution of optimised route plans for field area coverage: In the non – optimised practice of covering a field area, the route of an agricultural vehicle consists of a series of black – and – forth repetitions that follow a standard motif. Optimized field area coverage provides routes that cannot be executed without the implementation of navigation – aiding systems. This technology can offer reduction in the total non – working travelled distance.

- Fertilizers and soil management – determination of the precise part of an agriculture field that a tractor has collected soil samples for analysis, practice which is essential for decision support. Using a GNSS positioning receiver along with crop health information indentified on satellite imagery, a farmer is able to apply pesticides in a safer manner. Also fertilisers can be applied only to the locations of the field that is necessary. This saves money and allows for safer use of farming resources and minimises environmental pollution.

- Effective seed management - Certain agricultural seeds perform best when placed at spacing that allows the plants to benefit at maximum from the sunlight and soil moisture. A computerised soil map of a field on a computer fitted on the tractor along with a GNSS receivers can inform farmers where they are in the field, allowing the adjustment of seeding according to suitable spacing (Ikokou Blanchard G, 2013) .

The variety of tasks that can be automated is countless, from harvester spout adaptive positioning to grain truck convoy following. The addition of capabilities, and therefore of sensors, tends to be gradual according to producers' needs and the maturity state of technology.

The software device covers the Information layer, which can include the following tasks: Yield monitoring, 2D and 3D mapping, spraying flow & pressure, seed /fertilizer rate, supervising camera, grain / spray tank level, grain moisture screening, localization & attitude data, engine and vehicle.

In general the organization of the intelligent system embedded in the vehicle can be seen in the following figure where the system is distributed into the three layers (**Francisco Rovira-Más**, 2010):

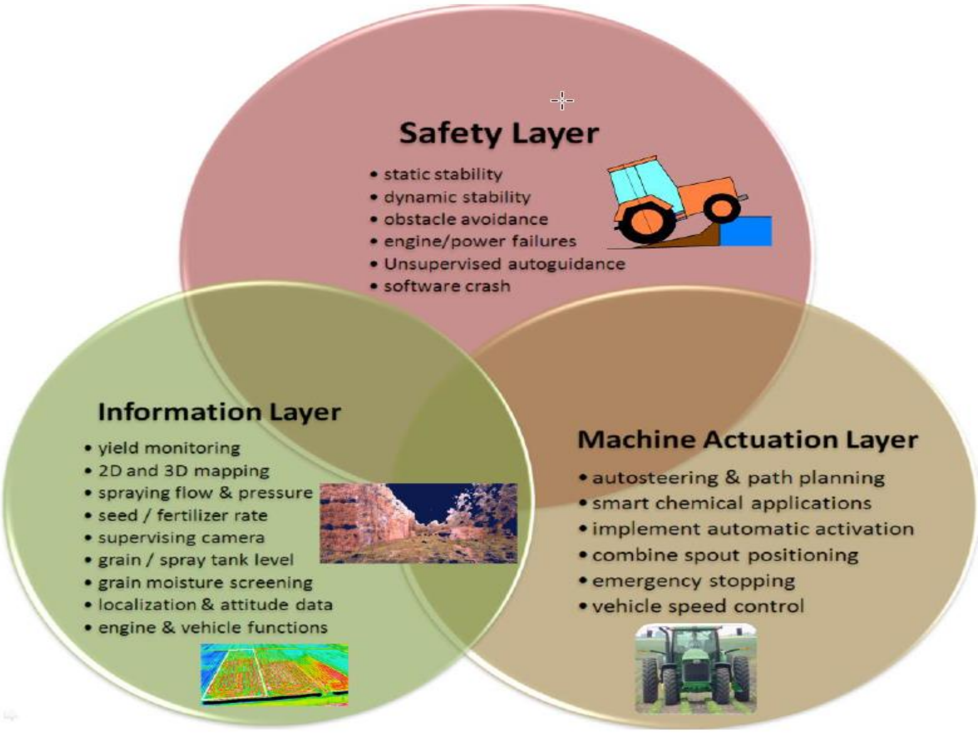


Fig 5: Organization of the intelligent system

Benefits resulting by the use of our service

Products use: For **in** field tasks - development and implementation of route planning methods on existing vehicles (**reuse** of existing vehicles by appropriate modifications), that minimise for example the total travelled distance.
For Whom: The results of a case study analyses (Batte, M. et al, 2005) suggest that a precision system will make most sense economically for **larger farms** who make **several applications annually** (e.g spraying) of relatively expensive for example spray materials. That is because most of the costs of the precision system relate to the fixed investment and these costs diminish per ha as farm size increases. Thus end users of the product are farmers and Agricultural Corporations owning a lot of has.

Where, How long and how often: Farmers or Agricultural Corporations of the Western World especially in countries like USA and Australia who performing agricultural operations throughout the whole season (e.g. groups of farmers cultivating different industrial plants like Corn, Wheat, Barley, Soy, Sugar beets e.t.c.) and own a lot of has of arable land.
How long – An estimation of 7-10 years in-field use, according to useful life-time of machinery (50%).

Expected value contribution that the service delivers to the user:

- **agricultural inputs** (fertilizers, pestisides, water etc) ↓
- **fuel consumption** ↓
- **productivity** ↑
- **soil compaction** ↓

In general the main benefits associated with our service are increased profit and improved sustainability. It aims to confine soil compaction to minimal area of permanent traffic lanes leaving, 80 - 90% of the field area without compaction. Also it can reduce production costs and increase yields while improving soil health and delivering other positive benefits to the environment (through, for example reduction of overlaps and time that the machinery remains idle during tasks execution).

There is a research about the use of a specific Mission Planner (B – patterns) for an autonomous tractor (Bochtis, D. et al, 2009) with satellite-based navigation system, which resulted to a reduction of the non-working distance during the field operations up to 50% in a range of different operations.
Another research found reduce energy consumption from 3 – 8% by the use of B – patterns compared with non – optimized work patterns which have a direct consequence in energy cost reduction in the field operations (Rodias et al, 2017).

A study of the benefits of integrating GNSS technologies in agriculture undertaken by Bowman [9], revealed a 68% increase in farm gross margins resulting from a better management of agriculture resources, 67% reduction in farm labour costs as a consequence of automation of agriculture vehicles guidance, 90% reduction in soil erosion caused by agriculture practice, 93% reduction in nitrogen loss through runoff and 52% reduction in CO_2 in comparison to traditional techniques employed in previous years (Bowman, K., 2008).

In a study (Balafoutis A et al, 2017), two vineyards planted with different grapevine cultivars (Sauvignon Blanc and Syrah) were examined for four consecutive growing seasons (2013–2016). The first year, the two vineyards were only studied in terms of soil properties and crop characteristics, which resulted in the delineation of two distinct management zones for each field. For the following three years, variable rate nutrient application was applied to each management zone based on leaf canopy reflectance, where variable rate irrigation was based on soil moisture sensors, meteorological data, evapotranaspiration calculation, and leaf canopy reflectance.
Vineyard input/output flow:

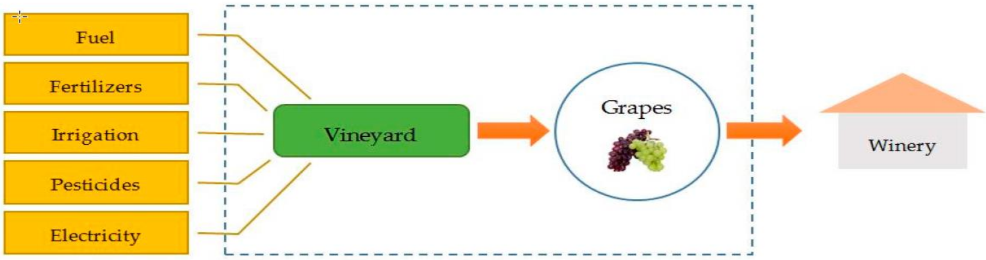


Fig 6 : Organization of the intelligent system

Life cycle assessment was carried out to identify the effect of variable rate applications on vineyard agro-ecosystems. The results of variable rate nutrients and water application in the selected management zones as an average value of three growing seasons were compared to the conventional practice. **It was found that the reduction of product carbon footprint (PCF) of grapes in Sauvignon Blanc between the two periods was 25% in total.** Fertilizer production and distribution (direct) and application (indirect) was the most important sector of greenhouse gas (GHG) emissions reduction, accounting for 17.2%, and the within-farm energy use was the second ranked sector with 8.8% (crop residue management increase GHG emissions by 1.1%, while 0.1% GHG reduction is obtained by pesticide use). **For the Syrah vineyard, where the production was less intensive, precision viticulture led to a PCF reduction of 28.3% compared to conventional production.** Fertilizers contributed to this decrease by 27.6%, while within-farm energy use had an impact of 2.2% that was positive even though irrigation was increased, due to yield rise. **Results suggest the use of a technology which optimally manages traditional field operations offers the greatest potential for reducing GHG emissions in both vineyard types. The potential of precision techniques to reduce the effect of viticulture on GHG emissions is noteworthy.**

Agricultural Practice	Type of GHG Measured
Fertilizers production and distribution	All types of GHG emissions from these processes [1]
Nitrogen fertilisers and manure application	N_2O, NO, and NH_3 soil emissions from N application and transformation processes of N in soils [2]
Pesticide production and distribution	All types of GHG emissions from these processes [3]
Tillage, Spraying, Dusting, Fertilizer and Manure application, Pruning, Transportation (on- and off-farm)	CO_2 from fuel use in tractor [4]
Irrigation	CO_2 from electricity use for pumping water [5]

Fig 7: Agricultural practices in agriculture and the respective greenhouse gas (GHG) emissions.

In general:

- The major GHGs produced in agriculture are: methane (CH4), nitrous oxide (N2O), and carbon dioxide (CO2).

- CO_2 arises directly from energy use in the farm (fuels, electricity) and from changes in above- and below-ground carbon stocks induced by land use and land use change.

Machinery production and maintenance has an impact on GHG emissions and energy consumption, while irrigation, fertilization, and nutrient management (especially nitrogen) are important variables in the environmental performance index of crop production

CASE STUDY – Energy savings by the application of our technology to *Miscanthus* Production

The cropping system of *Miscanthous giganteous* has been selected as a reference model to estimate energy savings through input reductions implementing optimized field-work patterns in cultivation, where our ICT /GNSS software application is implemented. *M. giganteous* is a high resistant plant with high adaptation capability to various climates and soils .It can survive in heat, frost, drought and flood, though its biomass yield may vary under different conditions. The crop prefers warmer climates though it can remain productive even temperatures below 12 ^{0}C and can be grown throughout Europe in reasonable yields.

Two original research articles ware taken into account:

1. Sopegno, A.; Rodias, E.; Bochtis, D.; Busato, P.; Berruto, R.; Boero, V.; Sørensen, C. Model for Energy Analysis of Miscanthus Production and Transportation. *Energies 2016*, 9, 392.
2. Rodias E, Berruto R, Busato P, Bochtis D, Grøn Sørensen C and Zhou K (2017). Energy Savings from Optimized In-Field Route Planning for Agricultural Machinery. *Sustainability 2017*

Materials and Methods

- System Boundary

The system boundary of the presented approach is shown in Figure 1. The system regards the in-field operations and the corresponding field-farm transports of the machinery and the materials applied in the field, and the biomass field-storage transportation. The indirect inputs in the system regard the embodied energy of machinery performing the field operations, the materials applied in the field, and the fuels. (Fig. 7).

- Inputs

The input parameters for the estimation process can be categorized in the following sets:

Production-related input parameters (e.g., field area, field-farm distance, and field-storage distance), and the crop features (e.g., yield, bulk density, moisture content of the harvested crop, and rhizome density).

Machinery-related input parameters. This set includes the tractors features (e.g., type of tractor, machine power, mass, and repair and maintenance coefficients), equipment features (e.g., operating width and equipment mass)

Operation-related input parameters. This set includes operational information (list of operations and years that each operation is performed, assignment of tractor to equipment for each operation) and parameters related to the execution of the operation (e.g., operating speed, and field efficiency)

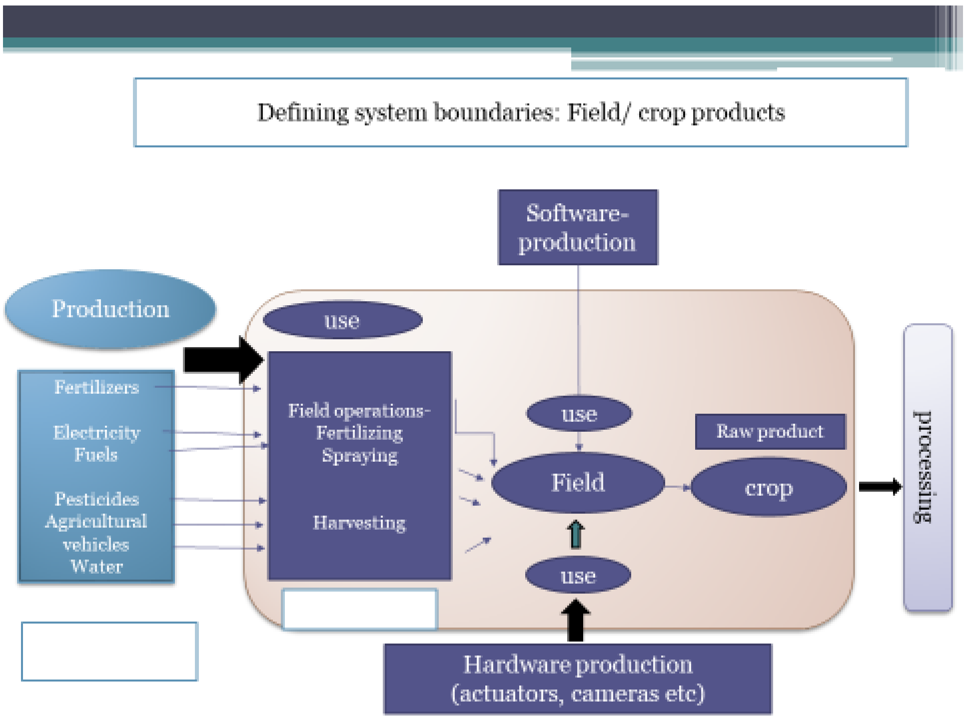
- Operations (In-Field Operation Part Module)

This module calculates the energy requirements for the execution of the in-field part of each operation.

RESULTS

The differences between the conventional agricultural practices and the proposed ones can be evaluated in terms of Carbon footprint or energy inputs. The functional unit in order to measure the Carbon Footprint is **kg of CO_2 /t (tonnes) of final product or total energy input in MJ/t of final product/year**

Fig *8.* *System boundaries of the energy inputs*



Estimations are made only for in field operations. Thus:

For the estimation of the energy cost of a crop, many agronomical related inputs are taken into account, such as field machinery and implements inputs (such as fuels and lubricants energy, embodied energy, weights, estimated lives, etc.), operation-related inputs (operating width, turning radius, area capacity, etc.) and agrochemical material-related inputs (such as applied dosages of fertilizers and agrochemicals).

Estimation of energy requirements to produce software application isn't part of our assessment and we have accepted as being minimal.

Table 1. *Energy requirements for each operation in the basic scenario-* ***Conventional***

Operation	Energy (MJ/ha)			
	fuel	Embodied energy machinery	Embodied energy material	total
Ploughing	882	138	0	1020
Cultivation	272	20	0	292
Disc-harrowing	437	49		486
Spraying	52	21	18160	18233
Fertilizing	520	210	48870	49600
Planting	534	76	69	679
Harvesting	24590	1270		25860
Irrigation				29700
Transport	2460	730	0	3190
TOTAL	**29747**	2514	67099	99360

Fuel consumption contributed of each operation (in 10 years)

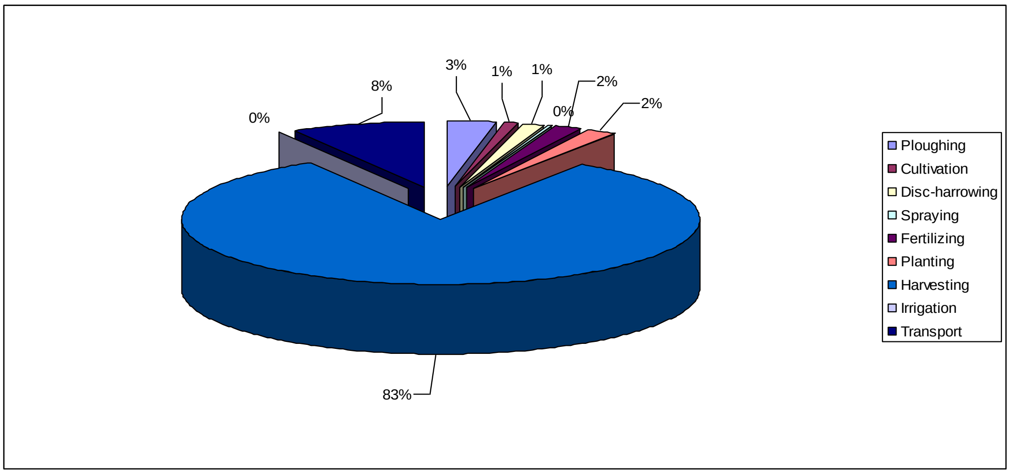


Fig. 9: Conventional model operation

Embodied energy contribution of each operation (in 10 years)

Energy required to produce any goods or services considered as if that energy was incorporated (embodied) into the product itself

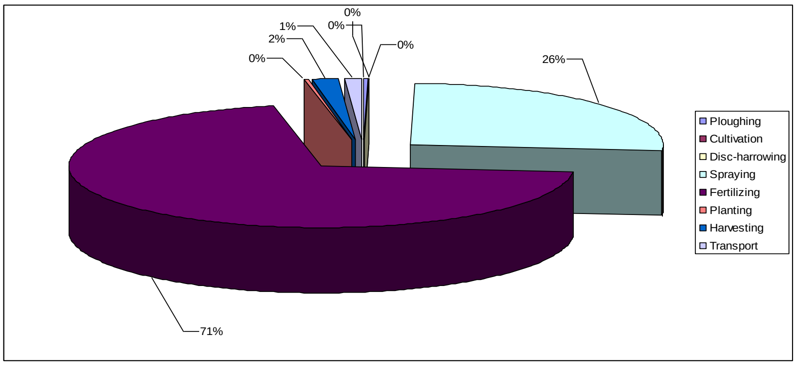


Fig 9: Conventional model operation

Energy contribution of each operation (in 10 years)

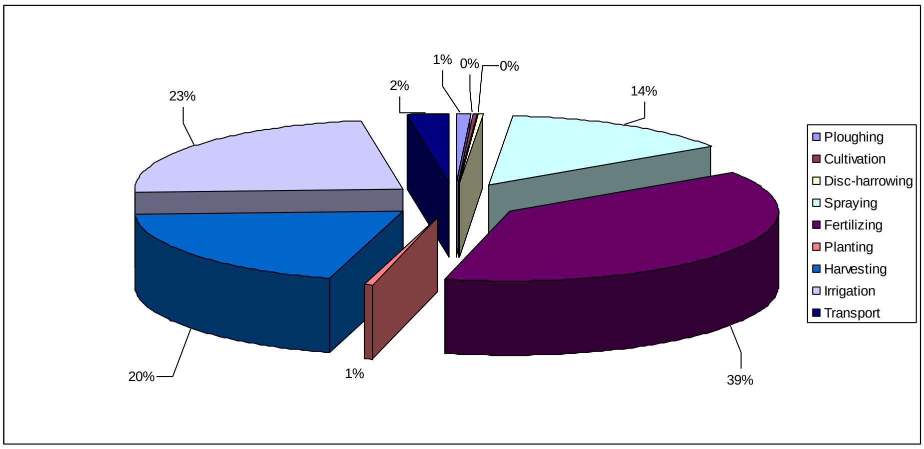


Fig.10 Conventional model application.

For the calculation of energy requirements for in-field operations in the case of our technology application:
The mean of the five different field shapes of the second article findings is taken into account as far as for the fuel energy savings (%) per operation and the mean embodied energy savings (%) per operation calculations.

Table 2. *Fuel energy savings (%)per operation – Miscanthus*

Ploughing	Disc - Harrow	Planting	Spreader	Harvesting
6.13 %	6.47%	4.32%	3.22%	6.02%

Table 3. *Embodied energy savings (%)per operation – Miscanthus*

Ploughing	Disc - Harrow	Planting	Spreader	Harvesting
6.13 %	6.12%	6.47%	3.21%	6.02%

For **materials**, an estimation of 3%, 5% and 10% reduction was taken into account. The same assumptions made for fertilizing and transport.
For **irrigation water**, although was not directly measured a reduction of 5% was considered acceptable. Irrigation has been considered as a field operation although it does not directly involve an agricultural machine. Reductions in energy requirement for irrigation water are connected with the reduction of compaction of soil (increase in irrigation efficiency). Less water is needed which also means reduction in energy requirements (electricity) for water pumping.

Taking into account: Production yield of the plant – 21, 87 t/ha and a 10 year period of production of the plant. All results are shown in tables (4-9).

Table 4. *First case: 3% reduction of materials*

Total energy input	**BEFORE**	**129060**	**MJ/ha**	**total energy input per year**	**12,906**	**GJ/ha/y**
	AFTER	**123848,88**	**MJ/ha**	**total energy input per year**	**12,385**	**Gj/ha/y**

- **A total of 4% reduction on energy inputs (MJ/ha) is achieved**

Table 5. *Functional unit before and after, in the first case*

Functional Unit	5901,23	MJ/t	5,90	GJ/t	before
Functional Unit	5662,96	MJ/t	5,66	GJ/t	after
Functional Unit	590,12	MJ/t/y	0,59	GJ/t/y	before
Functional Unit	566,30	MJ/t/y	0,57	GJ/t/y	after

➢ **-4%**

Table 6. *Second case: 5% reduction in materials*

Total energy input	**BEFORE**	**129060**	**MJ/ha**	**total energy input per year**	**12,906**	**GJ/ha/y**
	AFTER	**122488,10**	**MJ/ha**	**total energy input per year**	**12,249**	**GJ/ha/y**

Table 7. *Functional unit before and after, in the second case*

Functional Unit	5901,23	MJ/t	5,90	GJ/t	before
Functional Unit	5600,74	MJ/t	5,60	GJ/t	after
Functional Unit	590,12	MJ/t/y	0,59	GJ/t/y	before
Functional Unit	560,07	MJ/t/y	0,56	GJ/t/y	after

➢ A total of **5%** reduction on energy inputs (MJ/ha) is achieved by 5% reduction in materials.

Table 8. *Third scenario: 10% reduction in materials*

Total energy input	**BEFORE**	**129060**	**MJ/ha**	**total energy input per year**	**12,906**	**GJ/ha/y**
	AFTER	**119086,15**	**MJ/ha**	**total energy input per year**	**11,909**	**Gj/ha/y**

Table 9. *Functional unit before and after, in the third case*

Functional Unit	5901,23	MJ/t	5,90	GJ/t	before	
Functional Unit	5445,18	MJ/t	5,45	GJ/t	after	➢ **-7.7%**
Functional Unit	590,12	MJ/t/y	0,59	GJ/t/y	before	
Functional Unit	544,52	MJ/t/y	0,54	GJ/t/y	after	

A total of **7.7%** reduction on energy inputs is achieved by 10% reduction in materials.

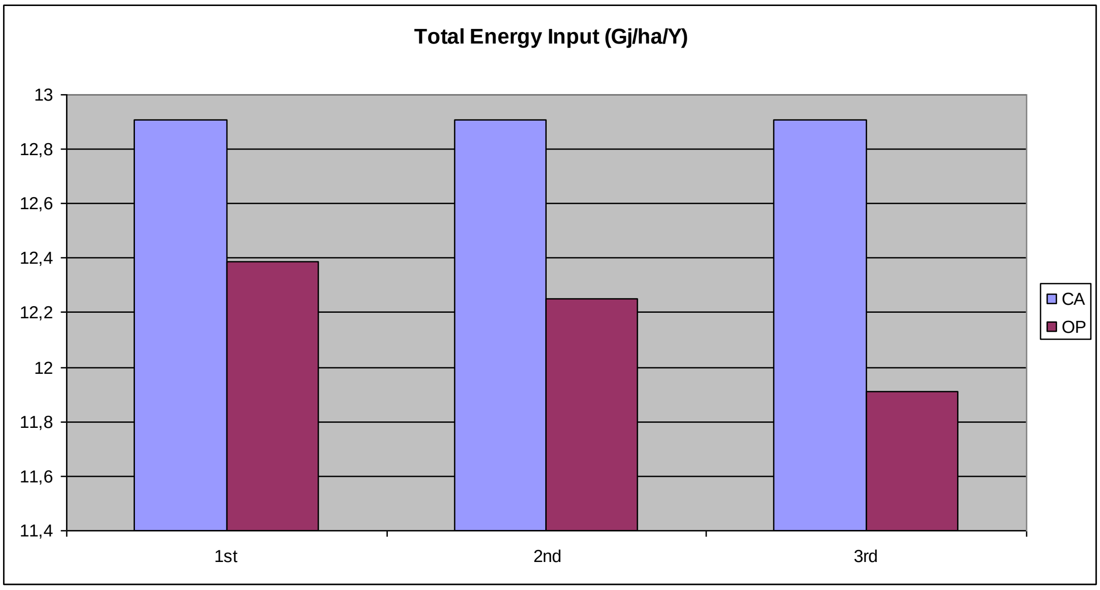


Fig 11: Total energy input (GJ/ha/y) Comparison of FU between CA (Conventional Agriculture) and OP (Optimized Agriculture) for the three different scenarios.

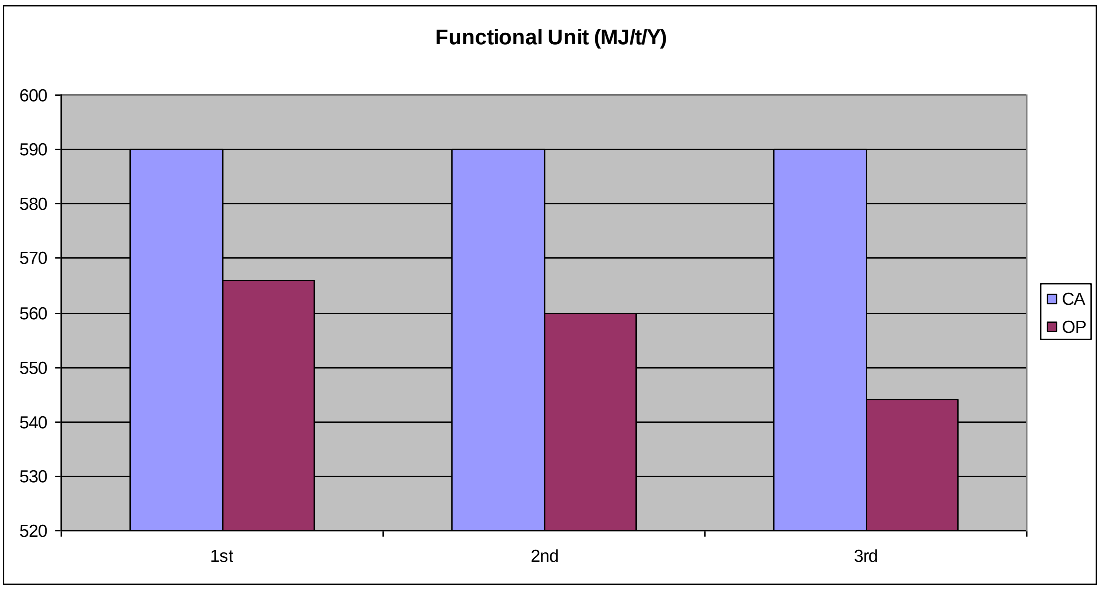


Fig 12: Functional unit (MJ/t/Y): Comparison of FU between CA (Conventional Agriculture) and OP (Optimized Agriculture) for the three different scenarios.

Efficiency of energy (EoE)

Energy output /Energy input ratio

First scenario (3% reduction of materials)
EoE - conventional Agriculture: **24,95**
EoE – Optimized Planning: **26**

Second scenario (5% reduction of materials)
EoE - conventional Agriculture: **24,95**
EoE – Optimized Planning: **26,29**

Second scenario (10% reduction of materials)
EoE - conventional Agriculture: **24,95**
EoE – Optimized Planning: **27,04**

(total energy output: 322GJ/ha per year)

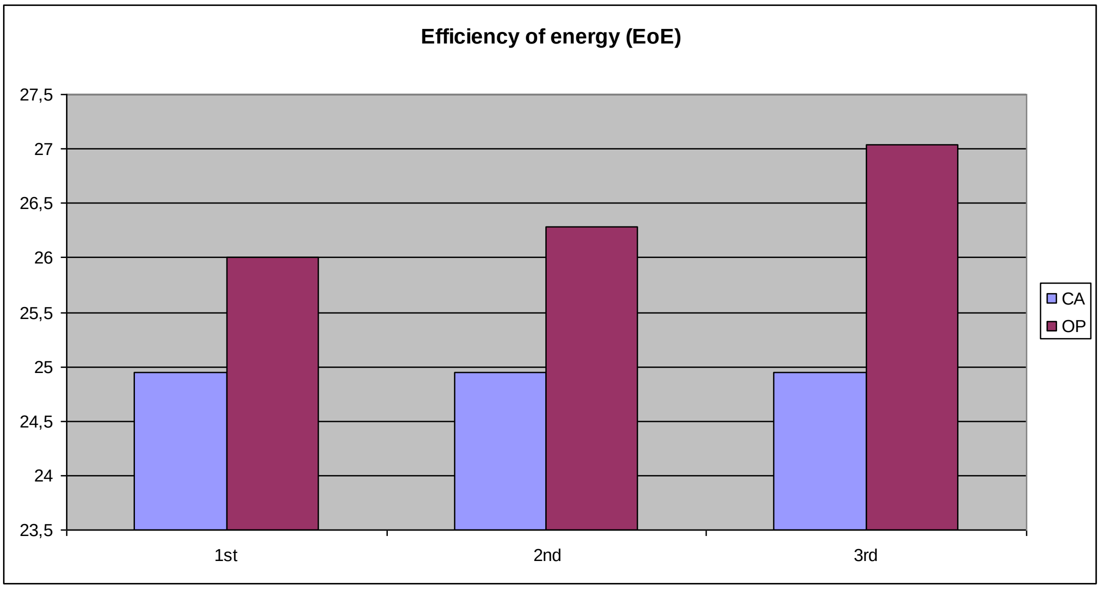


Fig 13: Efficiency of Energy (EoE): Comparison of EoE between CA (Conventional Agriculture) and OP (Optimized Agriculture) for the three different scenarios.

DISCUSSION

Environmental key areas for our business

All the aforementioned steps manifestly express the philosophy of our company, which being in tune with the current era primarily involves the promotion of an environmentally friendly strategy, generally applicable to the products generated and services provided by it. In this framework, our company's activity is determined by a very basic principle, namely offering *"the right treatment in the right place at the right time"* and in so doing it endeavors to result in eliminating as much as possible the negative environmental impact in order in turn to mitigate the grave risk of further jeopardizing the already fragile balance of the eco-system. Specifically, the company strives to meet the challenges posed by the major issue of the modern ecological catastrophe, by setting a series of goals, that founded on the site-specific optimum utilization can be concisely encapsulated in the following points:

1) **Rational use of the agricultural machineries**: this goal places great emphasis on the elongation of their life instead of their fast wear and therefore relatively easy replacement. This target is translated into the use of much fewer raw materials for the construction of new agricultural equipment and therefore the more sustainable handling of the resources available. In parallel, this approach by decreasing the purchase of agricultural machines simultaneously leads to the reduction of their production, which by definition means that the respective plants will spend less energy at all the stages of their production and distribution.
2) **Reduction of the energy spent by agricultural machineries:** this goal refers to the function of the high-power agricultural vehicles, which becomes less energy consuming and this primarily for two main reasons. On the one hand, our products and services promote the so-called "movement economy" since the agricultural vehicles utilizing our technology are designed in order to follow the most short route and therefore they spend less (conventional) fuels. Moreover the total in field-operational time is reduced so during the whole life time of a vehicle less energy per operation is required. On the other hand, they are properly adjusted in order to be able to consume green energy as well in terms mainly of solar energy instead of being based on the traditional and environmentally harmful emissions of fossil fuels.
3) **Reduction of the soil and water contamination:** This goal is achieved through a highly targeted operation of the tractors' work, taking into account that via the technology offered by our company there shall be an improved matching of pesticides application with crop needs. Consequently, while in the conventional farming for example pesticides are applied throughout the fields, causing their excessive usage and therefore polluting any point of the field concerned, in the agriculture supported by high technology they are

used with spatial precision. This means that the negative influence of the eco-system treasured in fields are much less negatively influenced.

4) **Precise irrigation:** this goal deals with a hot issue of agricultural operations since farmers due to the lack of appropriate environmentally sensitive mentality they usually opt for irrigating their fields in the most consuming way, wasting irrationally priceless water supplies. Contrary to that well-settled practice, the products and services offered by our company promote and establish a very accurate irrigation system that saves great amounts of water reserves, which in this way can be channeled to equally important usages, such for civilian consumption.
5) **Confinement of soil compaction:** this goal copes with a real scourge accompanying the modern agriculture mainly conducted by heavy machinery, the compaction of soil, known as soil structure degradation, as well. In particular, as such is defined the increase of bulk density or the decrease of the soil porosity caused by applied loads, which culminates in producing impenetrable layers within the soil that hamper the circulation of water and other nutrient ingredients. Against that background, the products and the respective services provided by our company by limiting the paths used in-field simultaneously restrict soil compaction to minimal areas of permanent traffic lines.
6) **Reduction of erosion risks:** this goal faces another challenge posed by the intensitivity of the agricultural activity. In particular, the latter is considered to be responsible for soil erosion due to the excessive tillage of land, which breaks soil into smaller particles. Our products and services aiming at the less possible usage of the field concerned, it contributes to some degree in minimizing the erosion risk.
7) **Optimum usage of the fields cultivated:** this goal, based on all the above factors, concerns the usage of fewer fields, which means that other areas of land can be released in order to be used as free green zones without being exposed to the, one way or another, harmful anthropogenic human intervention
8) **Environmental education of farmers:** this goal is founded on the completion of the aforementioned ones since their accomplishment gradually is reasonably expected to lead to a change of farmers' mentality by enabling them to become aware of the long-term consequences of the application of such environmentally friendly agricultural practices. In this way, the main objective is to make them use analogous methods in the other agricultural activities conducted by them.

Parameters to measure the environmental performance of product development:

- Material saving (% volume)
- Life cycle cost
- Improved sustainability through reduction of GHC emissions (% reduction of the overlaps, % losses and damage of the plants, % reduction in fuel consumption, % decrease in agricultural inputs like water, pesticides, and fertilizers etch.)

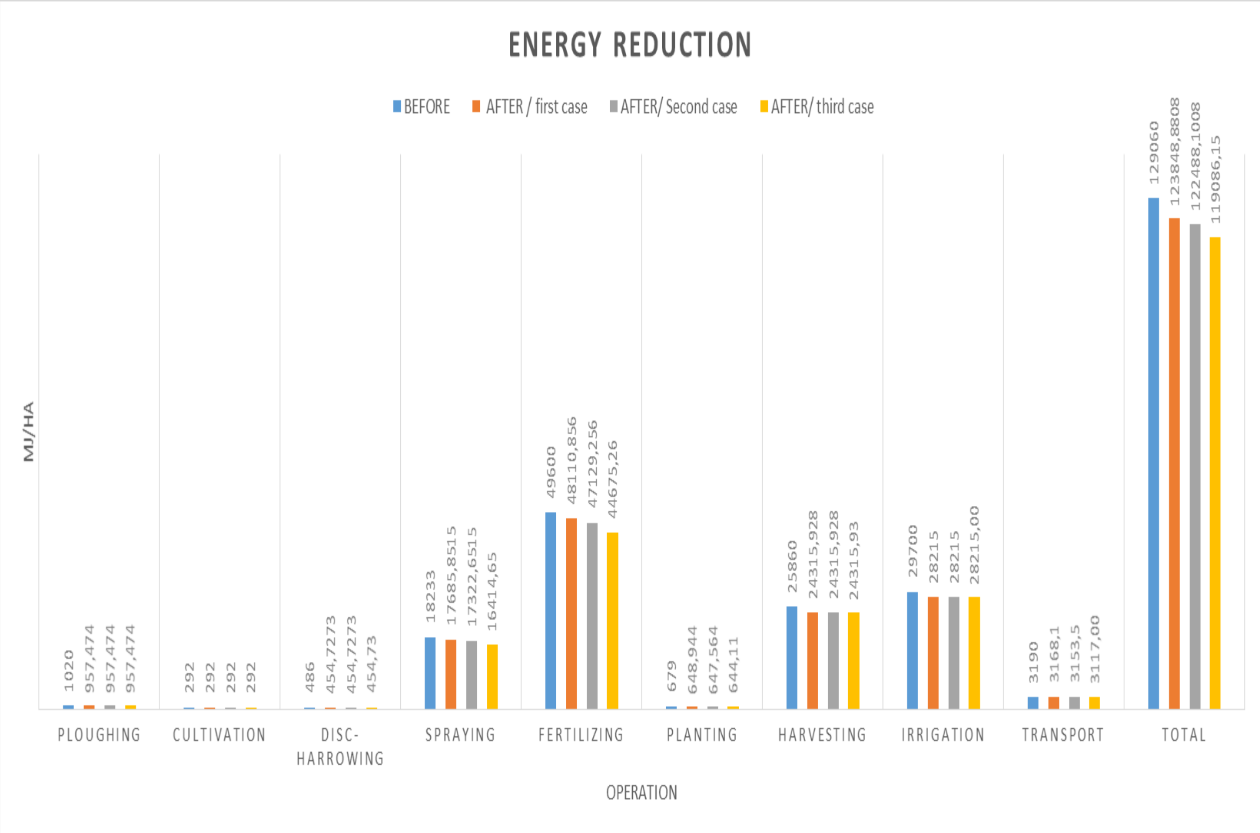


Fig.14 Energy reduction per operation in 3%, 5% and 10% scenario reduction of materials .

Conclusions

According to the energy reduction after the application of the satellite system, an equivalent removal has been calculated. If we take into account that in Europe there are 20000 hectares which are cultivated with *Miscanthus*, the total amount of energy reduction would be around 10422,2384 GJ/year , which is equivalent with the removal of 356.3 cars, that drives 15000km each year, as shown in Table 10.

Table 10. *Equivalent removal of (N) number of cars in each case*

Cases of reduction (%)	Number of cars removed (N)
First case (3%)	356,3
Second case (5%)	449,4
Third case (10%)	682,0

If we take into account that in Germany there is a 4.000.000 hectares prediction for cultivation of Miscanthus, the total amount of energy will be equivalent with the removal of 71260 cars that drives 15000km each year, as shown in Table 11.

Table 11. Equivalent removal of (N) number of cars in its case

Cases of reduction (%)	Number of cars removed (N)
First case (3%)	71260
Second case (5%)	89870
Third case (10%)	136390

References

- Batte Marvin T. and Ehsani Mohammad Reza (2005). Precision Profits: The Economics of a Precision Agricultural Sprayer System. *OSU AED Economics (AEDE-RP-0056-05)*
- Bowman, K. (2008). Economic and Environmental Analysis of Converting to Controlled Traffic Farming, Proc. 6th Australian Controlled Traffic Farming Conference, dubbo, NSW P 61-69. ACTFA.
- Bochtis DD, Vougioukas SC, Griepentrog HG. A mission Planner for an Autonomous Tractor. Transactions of the ASABE 2009; 52:1429-1440.
- Bochtis DD, Satellite based technologies as a key to enablers for sustainable ICT – based agricultural production systems. Procedia 2013: 4-8.
- Bochtis DD, Sorensen GC, Vougioukas SC. Path planning for in – field navigation – aiding of service units. Computers and Electronics in agriculture 2010; 74: 80-90.
- Ikokou Blanchard G., Transition from Global Positioning System to global navigation satellite system: Applications in agriculture practices (2013). SASGI Proceedings 2013 – Stream 1.
- Francisco Rovira-Más. Sensor Architecture and Task Classification for Agricultural Vehicles and Environments, *Sensors* **2010**, *10*, 11226-11247.
- Intelligent Technologies for Future Farming DaNet Thematic Workshop Horsens, Denmark, 27 March 2003. http://unsdsn.org/wp-content/uploads/2014/02/130919-TG07-Agriculture-Report-WEB.pdf
- Masanet E., Price L., Can S.D.L.R D., Brown Richard. (2005). Optimization of Product Life Cycles to Reduce Greenhouse Gas Emissions in California. Lawrence Berkeley National Laboratory. Berkeley, California
- Rodias E., Berruto R, Busato P, Bochtis D, Grøn Sørensen C and Zhou K. (2017). Life Cycle Assessment of Two Vineyards after the Application of Precision Viticulture Techniques: A Case Study. Sustainability **2017**, 9, 1997. www.mdpi.com/journal/sustainability
- Sopegno, A.; Rodias, E.; Bochtis, D.; Busato, P.; Berruto, R.; Boero, V.; Sørensen, C. Model for Energy Analysis of Miscanthus Production and Transportation. Energies 2016, 9, 392.
- Rodias E, Berruto R, Busato P, Bochtis D, Grøn Sørensen C and Zhou K (2017). Energy Savings from Optimised In-Field Route Planning for Agricultural Machinery. Sustainability
- Markus Sc, Enders Chr, Voigt Chr.A (2014) Assessing the cultivation potential of the energy crop *Miscanthus giganteous* for Germany. (http://onlinelibrary.wiley.com/doi/10/10.111/gcbb.12170/full)