BIONATURE 2015

The Sixth International Conference on Bioenvironment, Biodiversity and Renewable Energies

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BIONATURE 2015

Forward

The Sixth International Conference on Bioenvironment, Biodiversity and Renewable Energies (BIONATURE 2015), held between May 24-29, 2015 in Rome, Italy, continued a series of events covering topics on environment, biodiversity and invasion, and renewable and sustainable energies.

Environmental change awareness is a key state of spirit and legislation for preventing, protecting, and ultimately saving the planet biodiversity. Technical and practical methods for applying bio-agriculture for the public's health and safety are primary targets. The goal is the use of ecological economic stimuli in tandem with social and governmental actions preventing deforestation, pollution, and global warming. To cope with the climate and landscape changes advanced technical inventory of tools and statistics on lessons learned are needed to derive appropriate measure and plan accordingly.

Replacing the classical energy with alternative renewable energy (green energy), such as bioenergy, eolian energy, or solar energy is an ecological and economic trend that suggests important socio-economic advantages: using native renewable resources, increasing of selfsufficiency rate of energy and promoting use of clean energy, and that way, polluting emissions to the air will be reduced. Bioenergy is renewable energy derived from biological sources, to be used for heat, electricity, or vehicle fuel. Biofuel derived from plant materials is among the most rapidly growing renewable energy technologies. In several countries corn-based ethanol is currently the largest source of biofuel as a gasoline substitute or additive. Recent energy legislation mandates further growth of both corn-based and advanced biofuels from other sources. Growing biofuel demand has implications for U.S. and world agriculture. Eolian energy is currently used throughout the world on a large scale. In the past decade, its evolution shows its acceptance as a source of generation, with expressive growth trends in the energy matrices in the countries where this source is used Eolian energy is renewable and has very low environmental impact. To generate it, there are no gas emissions, no effluent refuse, and no other natural resources, such as water, are consumed. Photovoltaic technology makes use of the energy in the sun, and it has little impact on the environment. Photovoltaics can be used in a wide range of products, from small consumer items to large commercial solar electric systems. The event brought together the challenging technical and regulation aspects for supporting and producing renewable energy with less or no impact on the ecosystems. There are several technical integration barriers and steps for social adoption and governmental legislation to favor and encourage this kind of energy.

The conference had the following tracks:

- Green energy, plant diversity, environmental responsibility
- Forest landscape

The conference also featured the following symposium:

- **ENVIROSENS 2015*, The International Symposium on Remote Sensing for Climate and Earth Monitoring***

We take here the opportunity to warmly thank all the members of the BIONATURE 2015 technical program committee, as well as the numerous reviewers. The creation of such a high quality conference program would not have been possible without their involvement. We also kindly thank all the authors that dedicated much of their time and effort to contribute to BIONATURE 2015. We truly believe that, thanks to all these efforts, the final conference program consisted of top quality contributions.

Also, this event could not have been a reality without the support of many individuals, organizations and sponsors. We also gratefully thank the members of the BIONATURE 2015 organizing committee for their help in handling the logistics and for their work that made this professional meeting a success.

We hope BIONATURE 2015 was a successful international forum for the exchange of ideas and results between academia and industry and to promote further progress in the areas of environment, biodiversity and invasion, and renewable and sustainable energies. We also hope that Rome, Italy provided a pleasant environment during the conference and everyone saved some time to enjoy the historic beauty of the city.

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The Potential for Energy Diversification to Optimise Buildings' Energy Performance beyond Green Ratings

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***Abstract*—In the broader context of increasing demands for energy associated with expanding population and urbanisation, green building measures are an effective approach to relief the conflict between lowering ecological footprints of buildings and their rapidly growing energy demand. This paper assesses the green building rating tools and the fraction of Energy criterion as contributor to green star rating. The options that can be applied to improve building's energy consumption profile and, with that, contribute to greater green star rating of the building are further reviewed. Outdoor energy sources such as solar energy, as well as indoor energy sources, e.g. piezoelectric energy, are presented. The conclusion of this study is that it may be possible to achieve low carbon building footprint through the application of renewable energy sources, although some of the technologies remain as components of a concept that is yet to be fully and successfully demonstrated in practice.**

Keywords-sustainable building; renewable energy; BIPV; piezoelectric; bioenergy.

I. INTRODUCTION

Green building measures are defined as a sustainable, integrated approach, balancing environmental, economic, and social considerations with large scale of implemented innovative renewable technologies. However, the level of sustainability a building achieves is hard to be benchmarked.

A range of building rating tools have been developed to complement the knowledge about the level of sustainability and these rating systems are still in the process of improvement [1]. The most widely used building rating methods are Building Research Establishment Environmental Assessment Method (BREEAM), Leadership in Energy and Environmental Design (LEED), and Green Star [2, 3]; as summarised in Table 1.

There are similarities between these three schemes. They assess the building against multiple criteria in different categories including Land Use & Ecology, Water, Energy, Materials, Health & Wellbeing, Waste & Pollution, Management and Innovation [4-6]. Secondly, all these schemes are based on credit collecting systems that determine the level of sustainability and hence the building's rating classification [7]. Thirdly, all three rating tools have been developed into a series aimed at rating of a wide range of building types, both newly constructed and existing buildings [8]. All three rating methods are compared in Table 1. It demonstrates that the building rating methods have differences in their methodologies, evaluation scopes, weighting in credits and certification processes.

Among these worldwide building rating tools, a common acceptance should be noted that the weight of the Energy category has the most significant importance, accounting for nearly 25% of the total weightings. However, this may not be sufficient for buildings aiming for ultimate energy neutral or fully self-sustained. Under these circumstances, a recast of the Energy Performance of Buildings Directive (EPBD) will take force on 31 December 2018 by the European Parliament and the Council of the European Union in order to strengthen the energy performance requirements. The EPBD states that the nearly zero or very low amount of energy required should to a very significant level be covered by energy from renewable source, including renewable energy produced on-site or nearby [9].

According to the agreements among the building ratings, energy savings in the operating stage are believed to be the most substantial benefits of green buildings. A detailed review of 60 LEED rated buildings demonstrates that green buildings are on an average 25-30% more energy efficient compared to conventional buildings [10]. Energy savings in green building are achieved primarily by reducing electricity purchases from the power grid and secondly by reducing the peak energy demand. The reduced energy demand from power grids contributes to simultaneous reduction in greenhouse gas emissions. Li et al. [11] confirmed the energy saving potential by studying one of the most common green technologies, the photovoltaics panels in office buildings. They found that when semi-transparent PV panels are used together with dimming controls, a peak cooling load reduction of 450 kW was achieved. This was equivalent to annual building electricity saving of 1203 MWh, which contributed a reduction of 12% of the annual building electricity expenditure.

This evidence has indicated that the level of sustainability a building achieves is strongly coupled with the degree that renewable energy is integrated and utilised. The application of on-site renewable energy production provides possibility to reduce dependence on fossil fuel and mitigates emissions.

II. OUTDOOR ENERGY SOURCES FOR BUILDINGS

Renewable energy resources and their utilisation in buildings are key components of sustainable development [12]. In this context, the renewable energy resources and technologies applicable for integration into the green buildings are divided here into those that can generate energy from outdoor sources and indoor energy sources. One of the most important outdoor energy sources is solar radiation.

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A. Solar-Electrical and Building Integrated Photovoltaic

Solar energy is the most abundant and inexhaustible of all the renewable energy resources [13]. The amount of solar energy incident on the overall land area far exceeds the total world energy demand. Aside from the access and abundance of the solar resource, there are other positive features that make solar energy the ideal source of alternative energy. First, solar energy has the potential to provide electricity during peak demand times, due to the correlation between solar radiation and daytime peak electricity demand. Second, solar energy technologies have high compatibility and can be easily operated within other hybrid systems [14]. Third, solar technologies can offer distribution utilities ancillary services, such as grid support [15].

Photovoltaic (PV) is a technology used for generating electrical power by converting sunlight into direct current electricity using semiconductor materials. The PV system converts solar radiation into electricity that can be directly applied to power electronic appliances. Moreover, PV panels have no mechanically moving parts, hence are very easy to install and require very little maintenance. The overall cost-benefits analysis of applying PV in buildings were studied through Life Cycle Assessment (LCA) and the results were encouraging [16]. The carbon footprint of PV electricity is found to be favourable compared to the carbon footprint of electricity from fossil fuel based electricity and the energy payback time is significantly shorter than the expected lifetime of 30 years.

The traditional way of installing PV panels on to buildings is named Building Adopted Photovoltaic (BAPV), by mounting PV modules to a separate metal support structure on the roof. In contrast to the BAPV, Building Integrated Photovoltaic (BIPV) is defined as an architecturally integrated building component: the electricity producing modules are both a functional unit of the building and also part of the exterior building envelope, since these modules replace conventional building materials [17]. The fields of BIPV application are the roof areas of the building as well as facades, such as vertical walls, skylights, windows and external shading devices depending to the particular features of the photovoltaic materials.

With the development of Thin-Film (TF) technology, several types of TF modules with varied photovoltaic materials, such as amorphous (a-Si), micromorph (μm-Si), copper indium gallium selenide (CIGS), organic photovoltaics (OPV) and dye-sensitized cells (DSC) are accepted by the market due to their advanced features. For instance, by adding an encapsulating polymer of any colour or interferential coating, the TF modules can be tailor-made into any size and shape to satisfy the specific architectural requirements [18]. The coating and printing techniques which are known as the roll-to-roll printing technology, employed for the manufacture of the TF PV products, the manufacturing costs are expected to be much lower than the crystalline silicon solar cells in the next few years [19]. Furthermore, a prototype transparent photovoltaic cell with an ultrahigh visible transmission has been produced in the laboratory [20, 21]. By absorbing only infrared and ultraviolet light, letting visible light pass through the cells, the cell is able to reach a transmission of >55%±2%, which is sufficiently transparent for incorporation on architectural glass [20].

BIPV systems significantly extend the solar collecting area from roof only to the whole building skin, converting the largest vertical areas such as exterior walls and windows into electricity generators. They provide a vast vertical area directly exposed to the bright morning and early evening sunlight and hence the total electricity yield will be significantly increased [22].

B. Building Suitable Small-Scale Wind Turbines

Wind energy is an established and mature renewable energy alternative as it is clean, safe and available. However, the adaptability of mid-scale wind turbines in urban environment faces severe challenges because of the turbulence of the wind profile, noise pollution, limited size and space. In the past few years, many efforts have been made to harness wind energy and optimise the small-scale wind turbine performance. Until now, two main classified types of wind turbines, horizontal axis wind turbines (HAWT) and vertical axis wind turbines (VAWT) are developed for the turbulent urban wind profile [23].

HAWTs dominate the majority of the wind industry in urban environment [24], due to its extreme high efficiency in constant wind conditions. But because their axis of rotation of the blades is in a horizontal position, which needs to be pointed into the wind, the turbines are very sensitive for the wind direction changes. Moreover, the maximum size of HAWTs is strictly limited to 1.5-5 m in diameter, regarding the safety of wildlife and aircraft, esthetics and maintenance [25]. On the other hand, their counterparts VAWTs do not necessarily need to point in any particular wind direction. Since the main rotor shaft is arranged vertically, the vertical wind turbines can handle much higher turbulence and varied wind speeds and thus makes them much suitable in building mounting to overcome the turbulent nature of the wind in the urban environment. According to the size of building mounted wind turbines, the energy generating potential is reported from 100 W to 30 kW in the wind speed range from 10-20 m/s [25].

III. INDOOR RENEWABLE ENERGY ALTERNATIVES

A number of indoor renewable energies, such as waste heat, flowing water in internal drainage systems, electromagnetic waves and vibration, may also become important energy sources for buildings.

A. Water flow energy harvesting

Water flow is known as a useful source of mechanical energy which is essentially constant over extended period of time [26]. Water flow energy sources in the outdoor environment are widespread and used on the macro scale for electrical power generation as in hydroelectric plants. The streams of water found in the indoor environments also offer a great potential for energy harvesting. For instance, the grey and black water in the water pipes of a building drain system, as well as the rain water collected by the rain harvesting

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system which is installed on the building roof, have also been considered for smaller scale harvesting application. The hydro turbines that suit for small scale energy harvesting are designed and constructed according to the widely used large scale hydro turbines, Pelton (Figure 1a) and propeller (Figure 1b) turbines respectively [27]. The Pelton turbine is rotated by a jet of water discharged from a nozzle and is connected to a shaft. The water stream from an upper tank or high gravitational potential area sluiced out through the nozzle pushing the shaft and hence the energy is harvested in the form of electricity. It has been confirmed that the required power from a sensor node, 160 mW was obtained for HQ=0.14 ml/s with an efficiency of 11.3%. The energy harvest system using propeller turbine has a simple configuration. The turbine directly installed in the middle of the water pipeline could be pushed rotating by the down flowing water. Based on the test result, the turbine produced 900 mW of average power in a home irrigation system. In [28], a radial-flux energy harvester incorporating a three-phase generation principle is proposed for converting energy from water flow in domestic water pipelines. The energy harvester is able to generate from 15 mW at a flow rate of 5 l/min to 720 mW at 20 l/min. Therefore, it is possible to generate enough energy using very low water stream, without the need for energy storage.

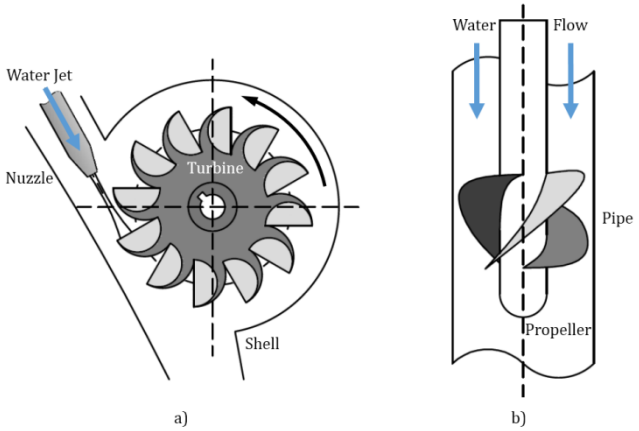

Figure 1. Hydro turbines: a) Pelton system; b) Propeller system.

B. Kinetic Energy Harvesting

The vibration-based energy harvesting, termed as piezoelectric energy generation, has received the most attention due to its ability to capture the surrounding ambient energy and then directly convert the applied strain energy into usable electrical energy and the ease at which they can be integrated into a system [29]. By connecting the energy harvester with a remote sensor, the harvest can be seen as an eternal energy source to replace the conventional battery, therefore eliminating the need for long term maintenance.

At present, a cantilever type vibration energy harvester is the most commonly used design due to its simple structure and the feature that can produce a large deformation under vibration [30]. For this type of design, the majority of the cantilever beam piezoelectric harvesters are used in micro-electro-mechanical system (MEMS) applications [31], aiming for vibration resources with high frequency and small mechanical stress. In order to extend receiving range of vibration frequency and to improve power conversion efficiency, a two-stage energy harvester design was suggested for the very low frequency vibration environment in the 0.2–0.5 Hz range [22], as shown in Figure 2a. This design contains two main components, a mechanical energy transfer unit linked with a vibration platform and secondary vibrating units composed of additional piezoelectric elements and vibrating beams fixed on one side. Ideally, when the initial impact effects on the platform, the mass attached on the mechanical energy transfer unit starts to vibrate in low frequency. The low vibration energy is then transferred to a much higher natural frequency vibration in the piezoelectric elements as the mass passes over and excites the piezoelectric beams.

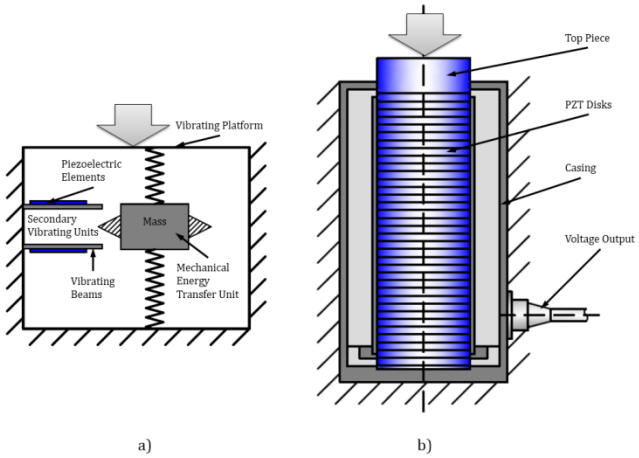

Figure 2. Two designs of the piezoelectric system: a) a two-stage energy harvesting approach based on the cantilever system [32]; b) a stack type piezoelectric harvester [33].

A stack type piezoelectric harvester is produced by stacking multiple layers of piezoelectric materials, as shown in Figure 2b. This results in a high mechanical stiffness in the stack configuration. Compared to the cantilever configuration, the stack type possesses a large capacitance and a higher capability of energy harvesting. It is suitable for a high force environment, such as a heavy manufacturing facility or in areas of large operating machinery [34]. With these features, the stack type piezoelectric harvester breaks the limitation from micro-scale energy harvesting in MEMS to macro-scale energy generation. In Israel, Innowattech has tested this type of energy harvester on highway to collect kinetic energy from passing cars as well as railways [35]. In the ideal conditions, the system is able to generate up to 200 kWh in every kilometre, which is enough to satisfy the energy demands from more than 800 families.

To date, several piezoelectric power generating products have been released to the market by different companies [32], such as Pavegen, Waynergy and Powerleap. The Pavegen piezoelectric harvester, Pavegen Tile, was demonstrated at the London 2012 Olympic Games. Twelve tiles were installed on a temporary walkway connecting the Station to the Greenway walking route at the Olympic Park. It was estimated that these tiles would receive more than 12

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million impressions from footfalls, generating 72 million joules of energy, which equals to 21 kWh of electricity. This amount of electricity was enough to illuminate the walkway for eight hours at full power during the night, and 16 daylight hours at half power [36]. A similar test was conducted at the University of Beira Interior. The Waynergy People prototype was deployed in the pavement at the main entrance of the Engineering Faculty. It was confirmed that 525 Joules or 0.15 Watt-hours of electric energy was harvested from 675 human steps by the Waynergy system during a peak hour, between 9 am and 10 am [37].

IV. ENERGY PRODUCTION FROM WASTES

Activities within the buildings contribute to considerable generation of organic waste that can be considered as a biomass and used for conversion into useful forms of energy. The main technologies for biomass processing can be classified into three categories: thermo-chemical, bio-chemical and mechanical extraction. There are three optional processes included in the method of thermochemical conversion: combustion, gasification and pyrolysis; while under the biochemical conversion category, there are two technologies available, which are digestion and fermentation. In the following, thermochemical pyrolysis and biochemical anaerobic digestion are introduced as two promising indoor renewable energy generating technologies.

A. Pyrolysis - A Thermo-Chemical Conversion

Pyrolysis is a method that converts biomass to more useful fuel products [38]. Under pyrolytic conditions biomass is heated to maximum temperatures of 450–500 °C in the absence of oxygen to produce a hydrocarbon rich gas mixture (biogas), an oil-like liquid (bio-oil) and a carbon rich solid residue (bio-char) [39].

Bio-char is a light black residue of the biomass material with very high surface area structure, which can retain soil-water and nutrients for plant growth. Recently, with the growing realisation of the importance of constructing human shelters that better conserve energy and water through appropriate insulation and architectural designs, bio-char is used as a substrate material for green roofs due to its positive influences on both plants and roof heat insulation [40]. The bio-oil is the dark brown liquid fraction of biomass generated during the pyrolysis process. It is expected to play a dominant role as a substitute for crude oil because of its CO_2 neutral and low sulphur content properties, because of a potential to improve fuel oil security and reduction in GHG emissions from fossil oil use. There are several options for bio-oil applications as fuel materials, which including combusting in boilers, diesel engines, gas turbines, and Stirling engines or being upgraded to higher energy density fuel before it can be economically used for energy production in standard equipment [41]. Biogas produced by pyrolysis is a mixture of volatile gases that consist primarily of CO_2, CO, methane and higher hydrocarbon compounds. Due to the combustable components in the biogas, biogas can be used as a fuel. Raveendran and Ganesh [42] compared biogas with fossil fuels. They found that the heating value of biomass pyrolysis gases are much lower than those of natural gas, but are comparable with those of blast furnace gas and producer gas. Although pyrolysis has gained much interest in the field of waste to energy conversion, the commercial proven pyrolysis plant in industrial scale remains limited.

B. Anaerobic Digestion – A Bio-Chemical Conversion

Anaerobic Digestion (AD) is a chain of interconnected biological reactions, where the organic matter is transformed into biogas, which is a gaseous mixture of methane, carbon dioxide and small quantities of other gases such as hydrogen sulphides, in an oxygen-free environment [43]. During the process, the biomass is converted by bacteria in an anaerobic environment, producing a gas with an energy content of about 20–40% of the lower heating value of the feedstock [44].

The methane component in the biogas produced from the AD process can be combusted in internal combustion engines or micro turbines for the production of electricity. Meester et al. [45] compared electricity production from domestic organic waste and energy crop digestion with reference to electricity. They highlighted an effect of vaporisation brought about by the AD technology, as it is able to convert almost all sources of biomass, including different types of organic wastes, slurry and manure to a high calorific value biogas. Komatsu et al. [46] proposed a mesophilic-thermophilic hybrid flow scheme which further enhanced the electricity production from municipal sludge, resulting in electricity production at a cost of 0.05 USD/kWh, lower than the market price of 0.009 USD/kWh. In relation to individual building heating, Esen and Yuksel [47] designed a hybrid system which integrated an AD reactor into a greenhouse. During a winter period the system maintained a constant self-sustained temperature of 27°C within the reactor, while the greenhouse temperature was able to be maintained at about 23°C. Recently, an on-site prototype anaerobic digester for high-rise building was proposed [48]. It demonstrated that the AD of sewage sludge and food waste from canteen has great potential to be used as an alternative renewable energy source.

V. CONCLUSION

In accordance with trends in building development where modern buildings are becoming complex and multi-functional, the green technologies can either be integrated into pre-standing urban buildings or designed into new buildings as part of a shift toward a more renewable, sustainable future. While the ideas and approaches are highly promising, they remain as components of a concept that is yet to be fully demonstrated in practice, due to investment costs and very small energy generated. These technologies are expected to contribute in the future exploitation and with further reduction in cost, because of the rapid break-through on material developments, design innovations as well as the manufacturing revelations. Further research needs to address their adaptability and their capabilities when integrated into buildings. Assessment of the sustainability of buildings beyond the green ratings should be considered by the energy diversification approaches to minimise energy consumption and GHG emissions.

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TABLE I. COMPARISON OF THE BUILDING RATING METHODS

Feature	Rating Method Name		
	BREEAM	LEED	Green Star
Launch Date	1990	1998	2003
Ratings	Pass/Good/Very Good/Excellent/ Outstanding	Certified/Silver/Gold/Platinum	One –Six Star
Weightings	Applied to each criterion (consensus based on scientific/open consultation)	All credits equally weighted, although the number of credits related to each criterion is a de facto weighting	Applied to each criteria category (industry survey based)
Information Gathering	Design/management team or assessor	Design/management team or Accredited Professional	Design team
Third Party Valuation	BRE	N/A	GBCA
Update Process	Annual	As required	Annual
Assessment Collation Fee	$4000-20000	$75,000	$4002-8004
Cost of credit appeals	Free	$500	$800
Building Covered			
New	+	+	+
Interiors	-	+	+
Core & shell	-	+	+
Existing	+	+	+
Renovated	+	+	+
Mixed-use	+	+	-
Category Weightings			
Management	15%	8%	12%
Energy	25%	25%	24%
Transport	N/A	N/A	12%
Health	15%	N/A	12%
Well-being	N/A	12%	N/A
Water	5%	5%	14%
Materials	10%	18%	12%
Land use	15%	N/A	8%
Ecology	N/A	5%	N/A
Pollution	15%	11%	6%
Sustainable Site	N/A	16%	N/A

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Comparative Studies of the Combustion of Raw and Heat-treated Straw and Combined Coal and Straw Pellets

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Abstract—**The main combustion process should be carried out in the regime of a fixed, forced ventilated bed for the efficient combustion of biofuel with low-melting ash in boilers with furnaces with a small height. After a certain period of time, a bed must be transferred into a state of turbulent fluidization, and then returned to its original state. So, the objective of the present work is to study the process of pellets combustion in such a bed (let's call it a pulsating bed). The suggested technology of combusting ensures prolonged steady combustion of fuel with moderate carbon monoxide emissions. Combined coal waste and straw pellets combust more stable with less carbon monoxide emissions than straw pellets. Preliminary torrefaction does not influence the stability of combustion, but allows reducing carbon monoxide emissions from the combustion of combined coal waste and straw pellets. Production of coal-straw pellets can apparently be considered as a new variant of the organization of coal and biomass co-combustion; and in the case of pellets torrefaction, it allows producing water-resistant fuel suitable for use not only in electric power stations, but also in small boiler-houses.**

Keywords-fluidized bed; fixed bed; straw pellets; coal's waste pellets.

I. INTRODUCTION

Analyzing the sources of raw materials for biofuel production, we came to the conclusion that the most accessible and annually renewable resource here is straw of different crops. Up to 120 million tons of straw of wheat, rye, oats and other cereal crops is annually gathered in Russia. As for winter wheat straw, we gather up to 60 million tons of it. Wheat straw is not used to feed cattle, but it is used in small quantities as bedding for the animals. Straw is often burned in the fields, as the value of its use as a fertilizer is questioned by many experts. According to our estimations, Russia can use up to 24 million tons of straw as fuel every year without harming either crop farming or agriculture. Straw as biofuel can be used for co-combustion with coal, including low-grade coal and coal waste (slurry). At the same time, we must bear in mind that straw is CO2 – neutral fuel, i.e., the same amount of carbon dioxide is released during the combustion as the plant absorbs during its growth. Taking into account the low bulk density of straw and granulometric composition of slurry (the particles are of size up to 0.2 mm), it makes sense to process this fuel into pellets, which are easy to transport and store. The feeding of pellets into a boiler furnace can be easily mechanized and automated. Such coal-straw pellets can be used in low-power boilers (up to 1 MW).

However, straw differs from wood and wood wastes, which are now most frequently used as fuel, by a high content of chlorine, silicon, phosphorus, and potassium. The presence of these compounds in straw contributes to the formation of slag agglomerates in the furnace, coherent deposits on the boiler heating surface and corrosion under these deposits. Thus, about 80% of the ash, produced during combustion of straw, can form slag in the boiler furnace. At the same time, only 10% of the ash, produced from the combustion of wood bark, can form slag; and the ash from stem wood does not form slag at all [1].

Some problems with the formation of slag agglomerates arise both during the combustion of agropellets in a fixed bed [2][3], or during the combustion of agropellets in a fluidized bed of inert material [4][5][6][7].

The process of straw combustion in a fixed bed is largely influenced by the mass flow rate of blasting air, and the dependence of straw combustion rate in a fixed bed on the flow rate of blasting air has an extreme character [8]. This severely limits the range of power control of the furnace.

It is possible to increase the efficiency of biofuel combustion, including the increase of the flow rate of blasting air, by the organization of the combustion process in a fluidized bed.

Bhattacharya et al. [9] shows that the efficiency of combustion in a fluidized bed of such high-ash biofuel as rice husks (ash content of 14% or more) can reach more than 85%. Moreover, in contrast to the combustion of biofuel in a fixed bed, the efficiency of a process increases with the increase of the flow rate of primary air during the combustion in a fluidized bed.

However, as mentioned above, during the combustion of biogranules with low-melting ash in a fluidized bed, we observe gradual agglomeration around a burning granule of the particles of inert material, which ultimately leads to defluidization and cessation of a combustion process.

It is possible to prevent defluidization by increasing the gas velocity in the furnace and by transferring a bed into the turbulent fluidization regime.

The use of turbulent fluidization technology can provide significant advantages. So, the combustion of carbon spheres in the turbulent fluidization regime passes at the rate of 1.5-3

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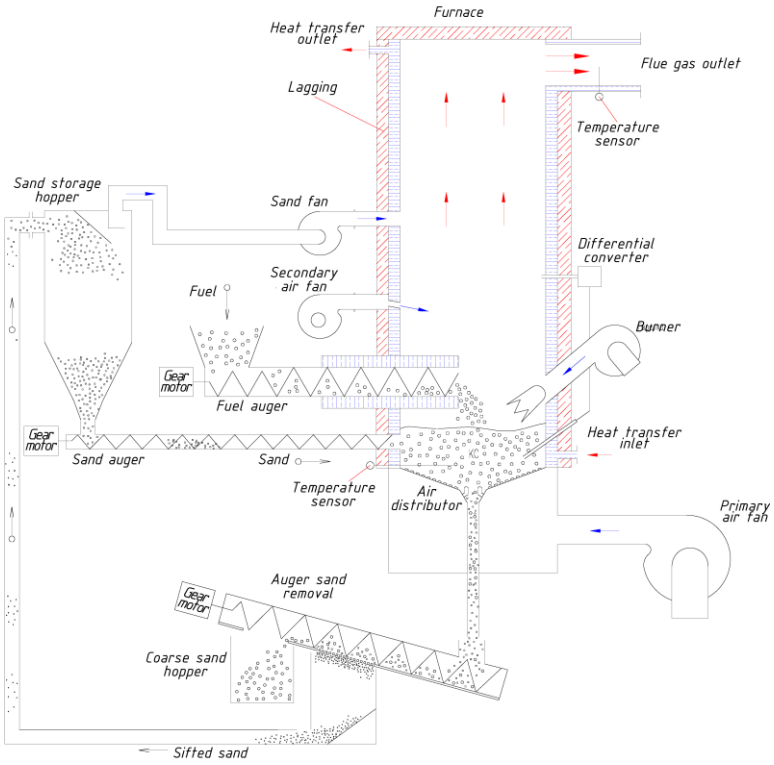

Figure 1. Functional scheme

times higher than in a bubbling fluidized bed [10], and it can be explained by significantly higher rates of mass transfer.

However, as applied to the technology of biofuel combustion in low- and medium-power boilers, i.e., in boilers with a small height of the furnace, the technology of combustion in the turbulent fluidization regime may be of limited use due to high fuel entrainment losses.

This implies the following proposition: the main combustion process should be carried out in the regime of a fixed, forced ventilated bed for the efficient combustion of biofuel with low-melting ash in boilers with furnaces with a small height. After a certain period of time, a bed must be transferred into a state of turbulent fluidization, and then returned to its original state. The transfer of a bed from one state to another can be implemented by changing the current frequency, energizing the drive of a blow fan. In this connection, the regulators of frequency can be programmed in a certain way, and the boiler operates automatically in both regimes, without operator's intervention.

So, the objective of the present work is to study the process of pellets combustion in such a bed (let us call it a pulsating bed).

II. The Experimental Unit

Figure 1 shows an outline of the experimental unit for studying the combustion of different types of solid fuel. The studies are conducted in the remote cylindrical furnace with inner diameter of 300 mm and height of 1000 mm above the air distribution grill. The furnace is water-cooled, and the cooling circuit of the furnace is inserted in the cooling circuit of the heat exchanger of flue gases.

The design of the furnace provides the tangential inlet of flue gases into the combustion can of the exchanger. This provides the post-combustion of volatile matters and the fallout of fuel and ash particles from gas flow.

The furnace is equipped with a hopper for solid fuel and with the device for fuel feeding in the furnace. Fuel inlet in the furnace is carried out at height of 350 mm above the air distribution grill.

The furnace is rested upon the air distribution grill; blasting primary air from the high-pressure fan is forced under this grill. The frequency of the electrical current, energizing the drive of the blow fan, is controlled, and it allows us to alter both the pressure of blasting air and blasting air flow rate by using a special program.

III. Methods and Materialse

In the course of the experiment, we combust pellets produced from straw, straw tor-pellets, combined coal slurry (70% by weight) and straw (30% by weight) pellets, and identical tor-pellets. Such a composition of pellets is conditioned by the fact that we want to get pellets with a maximum content of coal slurry. On the other hand, when the content of straw in the mixture is less than 30%, the obtained pellets are insufficiently strong. The cost of

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production of pellets from a mixture of coal slurry and straw is 60 euros/ton, and it is approximately equal to the cost of straw pellets production.

Torrefaction of pellets is carried out at temperature of 270°C during 30 minutes. In such a case, the weight loss of samples is the following: 85% for straw, 50% for coal slurry, and 60% for combined coal slurry and straw pellets.

The combined straw and coal slurry pellets have the following composition before torrefaction: sulfur – 1.2%, oxygen – 17.77%, hydrogen – 3.57%, nitrogen – 1.12%, carbon – 42.74%. After torrefaction these pellets have the following composition: sulfur – 1.27%, oxygen – 10.47%, hydrogen – 3.26%, nitrogen – 1.14%, carbon – 44.26%. The net calorific value of pellets increases by 17% and runs up to 19 MJ/kg by reducing the oxygen content and by increasing the carbon content. The hygroscopicity of pellets after torrefaction decreases from 11% to 7.1%.

As for straw pellets, the hygroscopicity of pellets decreases from 22% to 12% after torrefaction, and the calorific value increases by 18% and runs up to 18.3 MJ/kg.

Previously the authors of the following paper [11] determined the values of air flow rate, fed for the combustion in the same furnace as Figure 1 shows, where a bed, consisting of a mixture of straw pellets and solid combustion products, transits into a state of turbulent fluidization. The fractional composition of the bed is as follows: the fraction of particles smaller than 1 mm is 25%, the fraction of particles with the size from 1 mm to 2 is 27%, the fraction of particles with the size from 2 mm to 5 is 10% and the fraction of particles having a size from 5 to 6 mm is 38%.

We study the pressure drop pulsations in a bed during the combustion of pellets at different flow rates of blasting air. The measurement of the pressure drop in a bed is performed by means of the differential micromanometer “Testo – 525”. The digital signal from the micromanometer “Testo – 525” is transmitted every 50 mcs to a personal computer, which allows storing the measured values and subjecting them to a statistical analysis The micromanometer “Testo – 525” has a measuring range from 0 to 3 kPa, the maximum duration of continuous measurements is 60 seconds, the measurement error is 0.0015 kPa.

Figure 2 shows the alteration of the mean square deviation of pressure drop in a bed with increasing the flow rate of blasting air.

As is well known [12][13][14][15], a sharp drop in the values of mean square deviation of pressure drop pulsation in a bed is typical to the transition of a bed into the turbulent fluidization regime. Hence, for our case (combustion of

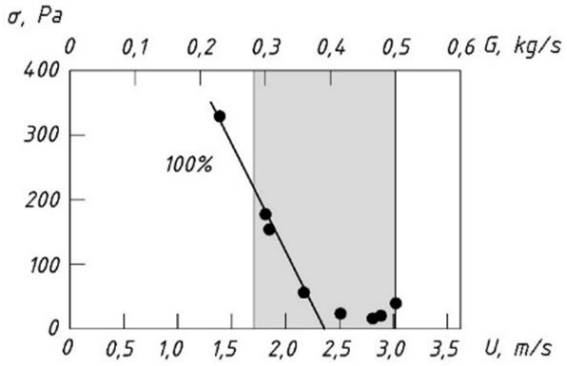

Figure 2. Mean square deviation of pressure drop in a bed vs. increase of flow rate of blasting air.

pellets in a bed of solid combustion products) a bed transits into a state of turbulent fluidization at air flow rate, divided by the cross sectional area of the empty furnace, of 2.0 – 2.5 m/s.

In the experiments, a bed is in a fixed state most of the time (flow rate of inlet blasting air in the furnace is 1.0 – 1.2 m/s), and then, as a result of increasing the current frequency, energizing the drive of a blow fan, a bed is abruptly transferred into turbulent fluidization (flow rate of blasting air is 2.0 – 2.5 m/s), and then a bed is again transferred into a fixed state. In the course of the experiments, we continuously measure the content of carbon monoxide, nitrogen oxide, carbon dioxide in flue gases, using the gas-analyzer VarioPlus; and we measure the content of sulfur oxides during the combustion of combined coal waste and straw pellets. The gas-analyzer VarioPlus provides the following accuracy: 0.2% for oxygen concentration, 0.02% for CO concentration measure, ± 5 ppm NO concentration measure.

The analysis of changes in the concentrations of the above mentioned substances in flue gases during the experiment allows us to evaluate whether the conditions for efficient combustion in furnace remain, and whether the formation of a significant degree of ash and slag agglomerates, preventing the normal combustion, does not occur. It is known, that the concentration of oxygen and carbon monoxide dramatically increases in flue gases and the concentration of carbon dioxide decreases during the formation of slag agglomerates and the cessation of normal combustion [4].

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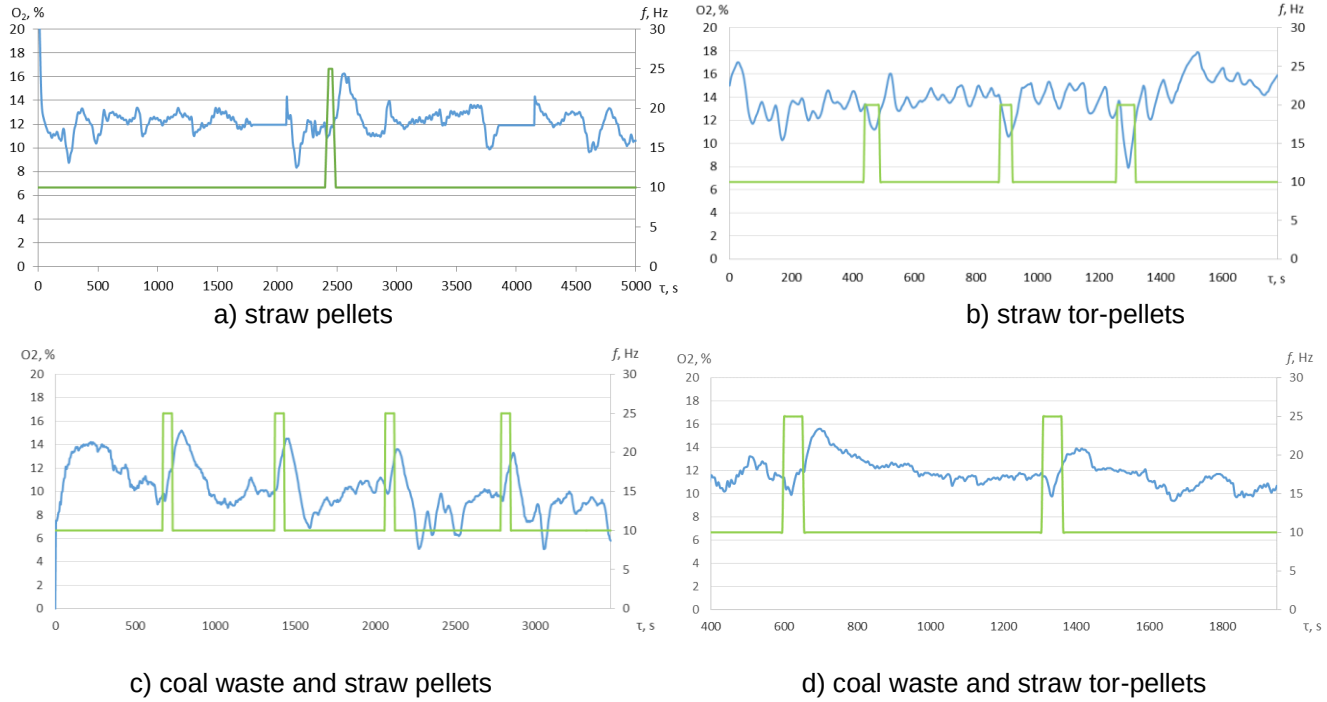

Figure 3. Changes in concentration of oxygen in flue gases from combustion of different pellets.

IV. RESULTS AND DISCUSSION

Figure 3 shows the curves of changes in the concentration of oxygen in flue gases during the combustion of straw pellets (a) and straw tor-pellets (b), combined coal waste and straw pellets (c) and combined coal waste and straw tor-pellets (d).

As Figure 3 shows, the combustion of all types of fuel at a periodic transfer of a bed from a fixed state into a turbulent fluidized state is stable, and the combustion process does not cease. The peaks of oxygen concentration are observed only after increasing the flow of air (after increasing the current

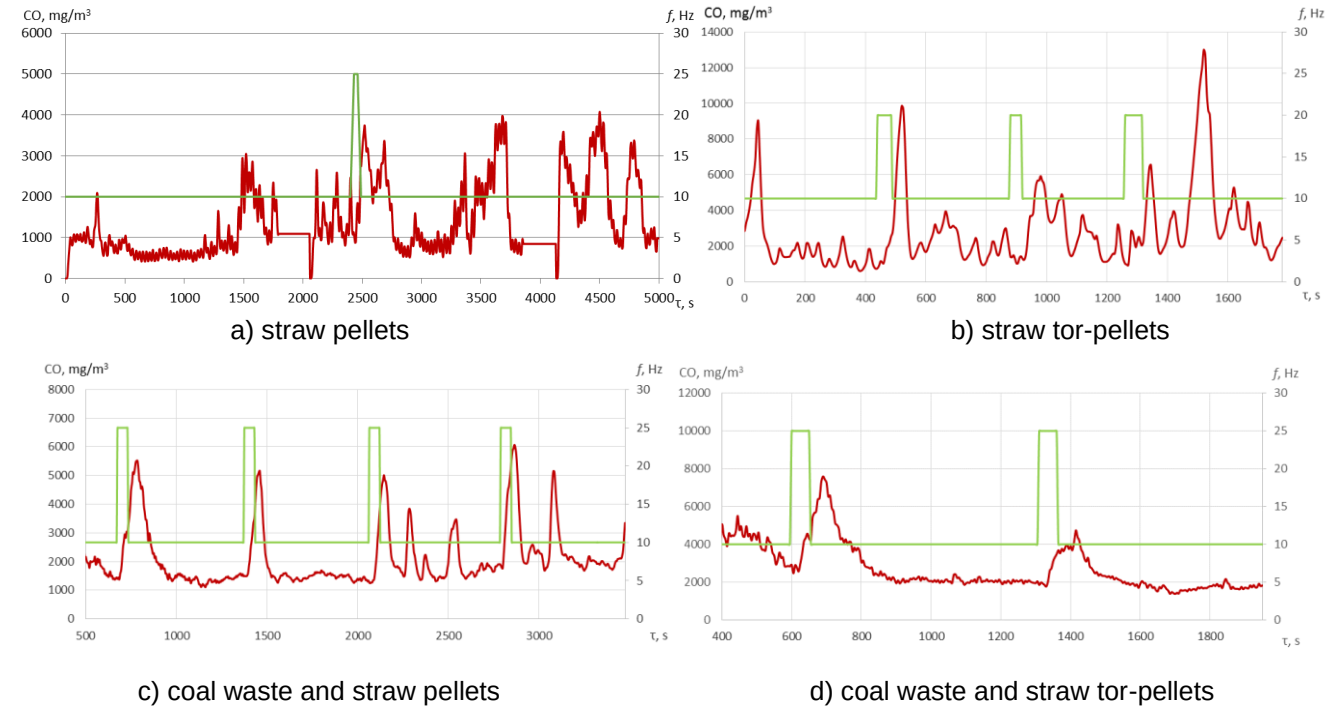

Figure 4. Changes in concentration of carbon monoxide in flue gases from combustion of different pellets.

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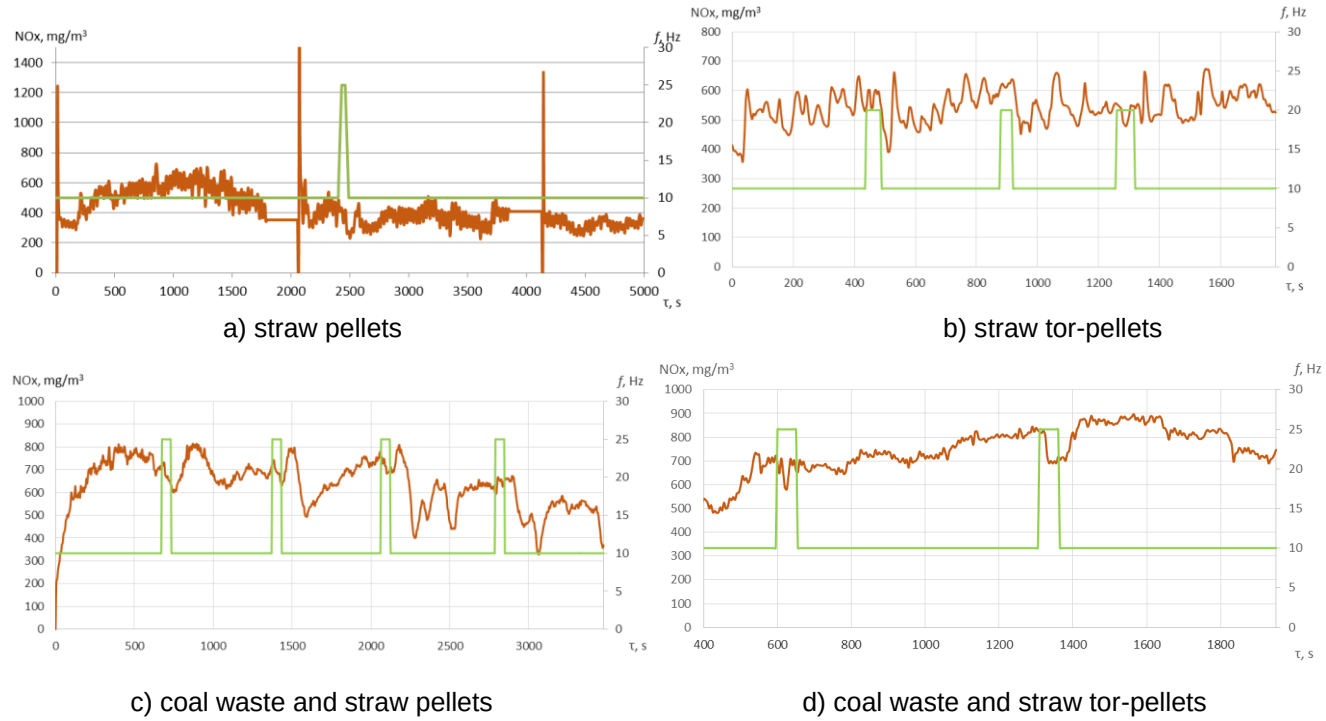

Figure 5. Changes in concentration of nitrogen oxides in flue gases from combustion of different pellets (symbols are identical with the previous figures).

frequency, energizing the drive of a blow fan). Therefore, ash and slag agglomerates are not formed in the furnace or their formation does not prevent the normal combustion (this may be in case of formation of brittle porous agglomerates, through which air can freely flow to the fuel).

The lowest oxygen concentration fluctuations occur in flue gases from the combustion of combined coal waste and straw tor-pellets. Such pellets have a minimum yield of volatile matters, and may be combusted in a bed in an arranged way.

We observe the lowest concentration of carbon monoxide in flue gases from the combustion of combined coal waste and straw pellets and especially from the combustion of coal-straw tor-pellets (Figure 4 c, d). This can be explained by a low content of volatile matters in these pellets. During the combustion of these pellets, sharp carbon monoxide emissions are observed only with increasing the flow rate of blasting air at the moment when the bed is transferred into the turbulent fluidization regime.

As for straw pellets, torrefaction of pellets practically does not influence the emissions of carbon monoxide; it evidently can be explained by the slight reduction in the yield of volatile matters (about 13%) as a result of such processing.

As a result of torrefaction the nitrogen content of pellets does not practically change and remains equal to 0.14 – 0.15% for straw pellets and 1.12 – 1.14% for combined coal waste and straw pellets. Therefore, the emission of nitrogen oxides from the combustion of all the types of pellets (Figure 5) is approximately the same (the emission of nitrogen oxides during the combustion of coal-straw pellets is higher).

So, the following question is obvious: why the emission of nitrogen oxides is about the same during the combustion of coal-straw pellets, which contain about 8 times more nitrogen than straw pellets, as during the combustion of straw pellets? In our opinion, there is a partial reduction of nitrogen oxides to molecular nitrogen by carbon of fuel when the flue gases flow passes through it.

V. CONCLUSION

1) The suggested technology of combusting fuel with low melting temperature of ash (combustion in a fixed bed with a periodic transfer of a bed into the turbulent fluidization regime) ensures prolonged steady combustion of fuel with moderate carbon monoxide emissions.

2) Combined coal waste and straw pellets combust more stable with less carbon monoxide emissions than straw pellets.

3) Preliminary torrefaction does not influence the stability of combustion, but allows reducing carbon monoxide emissions from the combustion of combined coal waste and straw pellets.

4) Production of coal-straw pellets can apparently be considered as a new variant of the organization of coal and biomass co-combustion, which in the case of pellets torrefaction allows producing water-resistant fuel suitable for use not only in electric power stations, but also in small boiler-houses.

5) The results of the study can be used for the boilers with any power, equipped with furnaces with a fluidized bed. In this case, the furnace of a real boiler can be considered as consisting of several furnaces with the inner diameter of 300 mm (the furnace with such a diameter is used in this study).

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Plant Diversity in the Area of Water Bodies near Kraków

Focus on Invasive Plants

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***Abstract*— Thirteen locations were examined referring to the vegetation and alien species in particular. The locations were the areas surrounding anthropogenic water bodies in Kraków and vicinity. Most of them were borrow pits left to the process of natural succession. In all the locations alien species, including neophytes were found. There were 22 neophyte species found in total, six of them invasive transformers. The most common was the Canada golden-rod (*Solidago canadensis*) found in eight locations. *Erigeron annuus* was found in 7 locations. *Bidens frondosa* and *Conyza canadensis* were found in 6 locations. Most neophytes were of North American origin. 16 archaeophytes were found. Four species had uncertain status. In urban areas, the presence of alien species does not make much problem, however in rural areas the monitoring is recommended.**

Keywords - alien species; invasive species; suburban areas.

I. INTRODUCTION

Water bodies (natural or artificial) and their vicinity make good environment for different plant and animal species. They attract both native and non-native species. In this paper, water bodies situated in Kraków and vicinity were studied. The region is not very rich in natural lakes, but includes a lot of artificial water bodies of various origin [1]: borrow pits of different size, made after the exploitation of limestone, gravel, sand or clay, fishing ponds, former decantation ponds, etc. In the process of natural ecological succession and sometimes due to human-made reclamation measures, these ponds get covered with vegetation and become inhabited by animal species [2]. Finally, they form semi-natural environment and can contribute to biodiversity of the region. The objective of the study is to examine the vegetation of selected water bodies in terms of the presence of non-native species. Non-native species can be divided into two groups: archaeophytes and neophytes. Archaeophytes are plants which arrived in the area in pre-historic or early historic times and neophytes were introduced in modern times and the usual border date is accepted as ca. 1500 – the discovery of the Americas [3]. Most archaeophytes in Europe arrived with the agriculture, as weeds growing in the fields and nowadays they make an integral part of the flora, although can also be invasive. Neophytes, however, are usually regarded more dangerous to biodiversity.

Crossbreeds between native and non-native plants are regarded non-native and if one of the parental species is neophyte, they are regarded neophytes [3]. Apart from the origin, the degree of naturalization in the environment is important; Pyšek et al. [3] distinguish casual species - alien species that do not form self-sustaining populations and naturalized species (synonym: established species) that form self-sustaining populations for several life cycles, as well as invasive species - a subset of naturalized species forming self-replacing populations, having the potential to spread over long distances. Tokarska-Guzik et al., after Richardson et al. [5] also differentiated the category of transformers (a subset of invasive plants) for the species which change the character of the ecosystems.

Section II gives the list of locations with a short description of every place and studying methods. The localities are also shown in the map – Figure 1. In section III the results are given, putting particular stress on alien species, presented in Table 1. The vegetation of each site was described in a separate sub-chapter. Chapter IV provides the conclusions and recommendations for further studies.

II. STUDY AREA AND METHODS

The study includes the vegetation in the areas of the water bodies in Kraków and vicinity in summer 2009 (in the case of Bagry and Zakrzówek also 2008). The studied areas are named below. More detail characteristics of the water bodies and their surrounding can be found in [2] [6] [7] [8]. The geographic distribution of the sites is presented in Figure 1. The area included:

1. Two borrow pits bodies situated south-east from the centre of Kraków in the area called Płaszów. The area of the bigger pond, called Bagry is 30.1 ha and the smaller one – called Staw Płaszowski (the Płaszów Pond) - is 9.0 ha. The ponds were formed after the exploitation of sand and gravel in 1930s. In Table 1., they are marked as BG and SP, respectively. The surrounding of SP is shown in figure 2.
2. Staw Dąbski (the Dąbie Pond, marked as D), 2.1 ha, situated in Kraków, east from the centre, was formed in 1930s after the exploitation of clay.

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3. Zakrzówek (marked ZK) - a borrow pit south-west from the centre of Kraków of 17.0 ha surface, was made in 1990s, after quarrying limestone.
4. The Pond of the Kaczeńcowa Street (KA) was, by the Resolution no. XXXI/405/07 of the City Council of Kraków, established Ecologically Useful Area – the area is 0.82 ha [9]. The pond is situated in the quarter of Nowa Huta in Kraków. The pond was formed as a result of clay exploitation.
5. Former decantation pond of the Steelworks in Nowa Huta in the region called Kujawy (marked KU) has the area of 2.9 ha.
6. Przylasek Rusiecki (PR) – a group of 11 gravel borrow pits of the total area of 82.19 ha, situated in the Eastern part of Kraków, quarter Nowa Huta.
7. Borrow pits in Wola Batorska (WB) – the gravel quarrying is still going on, so the area is changing.
8. Two borrow pits (exploitation of gravel) of Zabierzów Bocheński (ZB), commune of Niepołomice area of 13.03 ha and 3.43 ha, respectively.
9. The fish pond in Zakrzowiec (ZC) - area c.a. 2.5 ha, used for commercial angling.
10. Two ponds in the town of Niepołomice - Mokra street (0.7 ha) and Akacjowa street (0.3 ha), marked as MK and A, respectively.
11. Two borrow pits in the Commune of Liszki called Zalew na Piaskach and Budzyń, formerly known as 'Kryspinów' - area 24.5 ha and 20.3 ha, respectively, marked as ZP.

In each location, plots of the area of 16 m^2 were randomly chosen and the plants were identified to the species or – if not possible – to the genus. The plants were listed and identified as native, archaeophytes or neophytes, invasive or not invasive, harmful or not harmful. To identify the species and define their status literature data from Poland [4] [10] [11] and other countries of Central Europe [3] [12] [13] [14] were used.

III. Results and Discussion

The original data listing each species are available from the authors. In this paper, the results focus on alien species. Native species were mentioned, if predominant. Table 1. presents only non-native species or species of uncertain status. The list includes 22 neophyte species; six of them regarded invasive transformers. The most common of them were: *Solidago canadensis* L., found in 8 locations, and another invasive (although not harmful) plant – *Erigeron annuus* (L.) Pers. - found in 7 locations. *Bidens frondosa* L. and *Conyza canadensis* (L.) Cronquist were found on 6 locations. Most neophyte species, however, were represented only in one location. This particularly refers to casual species. These were mainly tree species, mostly located in the area of the Mokra Street. This was a residential area and some 'exotic' trees were planted there. Nevertheless, casual species were also found in less human-influenced place, such as Zakrzówek. Archaeophytes were represented by 17 species. Four species have uncertain status: one can be archaeophyte or neophyte depending on subspecies, which was not determined and the origin of three species is still debatable. The most widespread archaeophyte species occurred in 3 locations, which suggests that their ecological niches were narrower than in case of neophytes. On the other hand (data available from the authors), non-native species rarely covered more than 25% of the surface, while native species (like *Phragmites australis* (Cav.) Trin. ex Steud. or *Typha* spp.) could cover up to 95%.

The number of alien species in each location ranged from 1 or 2 in Zalew na Piaskach to 11 in the Mokra street in Niepołomice. Nevertheless in the Mokra Street planted trees distort the real picture. Considering this, the highest number of non-native species would be in Zakrzowiec (10). The detail characteristic of the studied sites looks as follows:

A. Bagry

The studies in Bagry were carried out on 2/07/2008 by Samalzhan Tleubayeva and Aleksandra Wagner in two locations: (1) – north-western shore of the water body and (2) – northern shore of the water body. Every location included coastal plant like *Juncus effuses* L., *Phragmites australis* (Cav.) Trin. ex Steud and *Schoenoplectus lacustris* (L.) Palla. In place (1) there was one alien species noticed - *Phalaris canariensis* L., a neophyte coming from southern Europe. This was the only alien species among 7 species scored in that place. The 2008 survey in place (2) did not show any alien species, however more detail survey of 3/08/2009 by Dario Hruševar, Aleksandra Wagner, Uroš Ljubobratović, and Barbara Patuła showed 7 out of 31 alien species, among which 3 (9.7%) were archaeophytes: *Melilotus albus* Med., *Melilotus officinalis* (L.) Lam and *Pastinaca sativa* L. The latter was considered native for a long time, but recent studies shown it was alien. Neophytes were represented by two (6.5%) species: *Acer negundo* L. and *Robinia pseudoacacia* L., both of them classified as invasive transformers. The encountered individuals (one of each species) were young and belonged to the undergrowth. The dominant plant was native: *Calamagrostis epigeios* (L.) Roth.

B. Staw Płaszowski (the Płaszów Pond)

In the western part the studies were carried out on 2/07/2008 by S. Tleubayeva and A. Wagner. Eleven species were found, among them two neophytes, none of them invasive: *Oenothera biennis* L. and one of North American ash trees, probably *Fraxinus pennsylvanica* Marshall, rarely encountered in natural environment in Poland. The study of

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20/08/2009 by D. Hruševar and A. Wagner in the eastern side of the pond showed 22 species, among which the dominant was *Phragmites australis* (Cav.) Trin. ex Steud. There were four (18.2%) neophytes: *Solidago gigantea* Aiton, *Solidago canadensis* L., *Bidens frondosa* L., *Acer negundo* L. – all of them invasive transformers. There was also a feral cultivar - *Humulus lupulus* L. Apart from the plot, yet another neophyte was found: *Conyza canadensis* (L.) Cronquist, according to [11] the most common alien species in Poland. The site is shown in figure 2.

C. Staw Dąbski (the Dąbie Pond)

The survey of 07/08/2009 by D. Hruševar, U. Ljubobratović and A. Wagner showed 12 species in the plot in the eastern part of the pond. Significantly dominant was *Typha angustifolia* L. There was only one alien species: *Bidens frondosa* L. In other parts around the pond 32 more species were observed, including *Nuphar lutea* L. – a native species protected by the Polish law – the only place in the city of Kraków where it occurs naturally. There were also three invasive neophyte plants: *Acer negundo* L., *Solidago canadensis* L. and *Erigeron annuus* (L). Pers. The first two are regarded transformer species and the latter is regarded harmless.

D. Zakrzówek

Two surveys were carried out in Zakrzówek – on 18/06/2008 by Samalzhan Tleubayeva, Aleksandra Wagner and Robert Mazur – on the hill in the eastern part of the area and on 13/08/2009, by D. Hruševar, U. Ljubobratović and A. Wagner – in the place slightly further from the previous one. In the first place 17 species were observed, including one archeophyte *Echium vulgare* L. and one neophyte *Fraxinus pennsylvanica* Marshall, usually occurring only as a cultivated plant. In the second place 23 species were present. Among them three alien species: *Lathyrus tuberosus* L. – an invasive, but not harmful archaeotype and *Juglans regia* L. – a cultivated tree (originating from Caucasus and Central Asia) and now expanding into natural and semi-natural habitats. Another invasive neophyte found there was *Solidago canadensis* L., classified as a transformer, although it was not numerous in that place.

E. The Pond of the Kaczeńcowa Street

Around the water body, 24 species were found, three of them neophyte invasive transformers - North American: *Bidens frondosa* L. and *Solidago canadensis* L. and Asian - *Impatiens parviflora* DC. The study was carried out on 19/08/2009 by D. Hruševar and A. Wagner

F. Former decantation pond of Kujawy

The survey, carried out on 19/08/2009 by D. Hruševar and A. Wagner, showed 15 species, where *Calamagrostis epigejos* (L.) Roth. was dominating. One of them was archaeophyte: *Melilotus albus* Medik and two invasive neophytes: *Conyza canadensis* (L.) Cronquist and *Solidago canadensis* L. Outside the plot, one more neophyte species - *Erigeron annuus* (L.) Pers. was observed as well as 8 native species, including *Centaurium erythraea* Rafn, protected by the Polish law.

G. Przylasek Rusiecki

The survey carried out on 25/07/2009 by D. Hruševar, U. Ljubobratović and A. Wagner in two places near the only pond available for bathing: in the eastern part of the shore, near the beach and in the northern part – a popular place for angling. In the first place 39 species were found and the ones occurring in the biggest quantities were *Achilea millefolium* L. and *Melilotus albus* Medik. The latter is archaeophyte and both are characteristic for pastures. In fact, the habitats in Przylasek Rusiecki are typically rural despite the fact of being situated in the administrative borders of the city of Kraków. Another archaeotype was *Humulus lupulus* L. Neophytes were represented by 3 species: *Erigeron annuus* (L.) Pers., *Bidens frondosa* L. and *Solidago canadensis* L. In the second place the most common species was *Euphorbia virgata* Waldst. et Kit. This plant has an uncertain status in the Polish flora. There were an archaeopophyte species - *Melilotus albus* Medik. Apart from the neophyte plants known from the previous place: *Erigeron annuus* (L.) Pers. and *Solidago canadensis* L., four more species: *Medicago sativa* L., *Conyza canadensis* (L.) Cronquist, *Oenothera biennis* L. and a tree species: *Populus* × *euramericana* (Dode) Guinier ex Piccarolo were found.

H. Wola Batorska

The survey was carried out on 19/08/2009 by D. Hruševar and A. Wagner near the ponds in the eastern part of the complex of the water bodies. Place (1) was near the bigger pond and place (2) near the smaller pond. In place 1 36 species were found, among them 7 of alien origin: archaeophytes: *Matricaria perforata* Merat., *Capsella bursa-pastoris* (L.) Medik. and *Lactuca serriola* L., all of them invasive, but usually not harmful. *Panicum miliaceum* L. was also found. The subspecies was not defined, which in this case, does not allow stating in the plant was archaeophyte or neophyte, but it is invasive. Other alien species included *Phalaris canariensis* L., *Acer negundo* L. and *Bidens frondosa* L. In place (2) twelve species were found, including one archaeophyte: *Echinochloa crus-galli* (L.) P.Beauv. and one neophyte: *Conyza canadensis* (L.) Cronquist. In the area outside the plots one more neophyte was found: *Picea pungens* Engelm. The specimen found was in a very poor shape. Probably it was deliberately planted.

I. Zabierzów Bocheński

On 10/08/2009 D. Hruševar, U. Ljubobratović and A. Wagner surveyed two plots in the area: (1) in the central part of the complex – near the beach and (2) in the southern part of the area.

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In place (1) 34 species were found, where *Bolboschoenus maritimus* (L.) in the part near water and *Trifolium repens* L. – further from the shore were predominant. There was only one neophyte: *Bidens frondosa* L. and one of uncertain status *Cirsium vulgare* (Savi) Ten. In site (2) there were 39 species recorded and only one - *Solidago canadensis* L. was neophyte. There were also *Rumex crispus* L. – a plant of an uncertain status and *Prunus cerasus* L. – a cultivated species, in that site occurring as feral. In the water a protected by the Polish law species was found - *Salvinia natans* (L.) All.

J. Zakrzowiec

The survey was carried out on 17.08.2009 by D. Hruševar and A. Wagner in two sites. Site (1) was close to the pond and site (2) was in the place of the pond that was dried out a few years before the survey. In the site (1) 37 plant species were found. The dominant species was *Phragmites australis* (Cav.) Trin. ex Steud, covering more than 75% of surface. There were only two neophytes: *Erigeron annuus* (L.) Pers. and *Conyza canadiensis* (L.) Cronquist and one archaeophyte: *Lactuca serriola* L. In place (2) 24 species were found. The dominant one was an archaeophyte *Echinochloa crus-galli* (L) P.Beauv. Other archaeophytes included *Setaria pumila* (Poir.) Schult. and *Matricaria perforata* Merat. There was also *Cirsium vulgare* (Savi) Ten., an invasive plant of uncertain status. Neophytes included *Bidens frondosa* L., *Conyza canadiensis* (L.) Cronquist and *Erigeron annnus* (L.) Pers.

K. The Mokra Street – Niepołomice

The survey was carried out by D. Hruševar and A. Wagner on 17/08/2009. There were 31 plants found in the plot near the pond. Archaeophytes included: *Pastinaca sativa* L. and *Setaria pumila* (Poir.) Schult. Neophytes were: *Erigeron annuus* (L.) Pers., *Conyza canadensis* (L.) Cronquist and *Veronica persica* Poir. The presence of privet *Ligustrum vulgare* L. could be of anthropogenic or natural origin, but anthropogenic origin was more likely. The water body was in the residential area and many non-native species were planted: *Picea pungens* Engelm., *Liriodendron tulipifera* L., *Catalpa bignonioides* Walter, *Pinus nigra* Arnold, *Abies concolor* (Gordon) Lindl. ex Hildebr. and *Thuja* spp.

L. The Akacjowa Street – Niepołomice

Around the water body 40 plant species were recorded on 17/08/2009 by D. Hruševar and A. Wagner. There were two archaeophytes: *Lactuca serriola* L. and *Echinochloa crus-galli* (L.) P. Beauv., as well as three neophytes in the area: the bur marigold *Bidens frondosa* L., black locust *Robinia pseudoacacia* L. and horseradish *Armoracia rusticana* G. Gaertn., B. Mey. & Scherb. The latter is a cultivated plant, invasive, but not harmful.

M. Zalew na Piaskach

The place selected for the survey on 31/07/2009 (by D. Hruševar, U. Ljubobratović and A. Wagner) was in the area where the pond was shallower and overgrown by macrophytes such as *Typha latifolia* L. There were 40 vascular species and a moss – *Sphagnum.* There was one neophyte there: *Erigeron annuus* (L.) Pers.

The study showed the presence of alien plants, including neophytes in each location. Many of them are invasive, although only in few localities they were dominant or even made a significant proportion in the land cover. The most commonly found species (in terms of the number of locations) - *Solidago canadensis* - never covered more than 25% and often less than 5%. This can confirm an interesting study done by Orczewska [15] suggesting that some native species (such as *Urtica dioica* L. and *Galium aparine* L.) can be more dangerous for the habitat than neophytes (such as *Solidago gigantean* Aiton).

The study also confirms the data suggesting higher presence of non-native plants in human-influenced areas [4] [14]. The lowest number was scored in Zabierzów Bocheński and Zalew na Piskach, places relatively distant from residential areas. On the other hand the presence of non-native species in the areas with already strong human influence is not so harmful. The real danger for biodiversity is the presence of invasive plants in protected areas. The eastern part of the study area is situated near the Niepołomice Forest, a place with some amount of strictly protected areas. Fortunately in a nearby place like Zabierzów Bocheński the influence of invasive species is small (two species of *Solidago*), nevertheless cannot be neglected.

IV. CONCLUSIONS

Although alien species occurred in every location in the study area, they never dominated. Among the alien species particular attention should be paid on invasive transformer species: the ash-leaved maple (*Acer negundo*), black locust (*Robinia pseudoacacia*), Canadian golden rod (*Solidago canadensis*), giant goldenrod (*Solidago gigantea*), bur marigold (*Bidens frondosa*) and small-flowered touch-me-not (*Impatiens parviflora*). The Canadian golden rod was the most common of them.

In the residential areas many alien tree species are grown. Apart from two species (the ash-leaved maple and black locust) they are not invasive and most of them can only sporadically found in the wild.

Further monitoring of invasive plant species is necessary, also because of the perspective of climatic changes. Warming the climate will provide better conditions for the reproduction of southern species so that they could become invasive. The example can be the common walnut (*Juglans regia*), which was found in one location, but, according to literature [11] this species is in the initial phase of invasion, so it is likely to extend its range.

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Tab. 1. NON-NATIVE (OR SUSPECTED TO BE NON-NATIVE) PLANTS OF IN THE AREA OF WATER BODIES NEAR KRAKÓW

N – neophyte, A – archaeophyte

	BG	SP	D	ZK	KA	KU	PR	WB	ZB	ZC	MK	A	ZP	
Acer negundo	+	+	+					+						N, invasive, transformer
Robinia pseudoacacia	+										+			N, invasive, transformer
Juglans regia				+										N, cultivated, in the first phase of invasion
Populus x euroamericana							+							N, not invasive
Pinus nigra											+			N, not invasive
Picea pungens								+			+			N, casual
Abies concolor											+			N, casual
Thuja sp.											+			N, casual
Liriodendron tulipifera											+			N, casual
Catalpa bignonioides											+			N, casual
Fraxinus pennsylvanica		+		+										N, casual
Solidago canadensis	+	+	+	+	+	+	+		+					N, invasive, transformer
Solidago gigantea		+												N, invasive, transformer
Bidens frondosa			+		+			+	+	+		+		N, invasive, transformer
Impatiens parviflora					+									N, invasive, transformer
Conyza canadensis		+				+	+	+		+	+			N, invasive, weed
Veronica persica											+			N, invasive, weed
Phalaris canariensis	+							+						N
Armoracia rusticana												+		N, invasive, not harmful
Medicago sativa	+						+							N, invasive, not harmful
Erigeron annuus	+		+			+	+			+	+		+	N, invasive, not harmful
Oenothera biennis		+					+			+				N, not invasive
Panicum miliaceum								+						A or N, depending on subspecies
Echinochloa crus-galli								+		+		+		A, invasive, weed
Setaria viridis			+							+				A, invasive, weed
Setaria pumila										+	+			A, invasive, weed
Cichorium intybus			+											A, invasive, not harmful
Marticaria perforata								+		+				A, invasive, weed
Lactuca serriola								+		+		+		A, invasive, not harmful
Capsella bursa-pastoris								+						A, invasive, not harmful
Papaver rhoeas			+											A, invasive, not harmful
Senecio vulgaris			+											A
Melilotus albus	+						+							A
Melilotus officinalis	+													A
Pastinaca sativa	+	+	+											A
Humulus lupulus		+					+							A
Echium vulgare				+										A
Lathyrus tuberosus														A
Odontites verna				+										A
Cirsium vulgare								+	+	+				Uncertain status, invasive, not harmful
Euphorbia virgata							+							Uncertain status, not invasive
Rumex crispus													+	Uncertain status
	BG	SP	D	ZK	KA	KU	PR	WB	ZB	ZC	MK	A	ZP	

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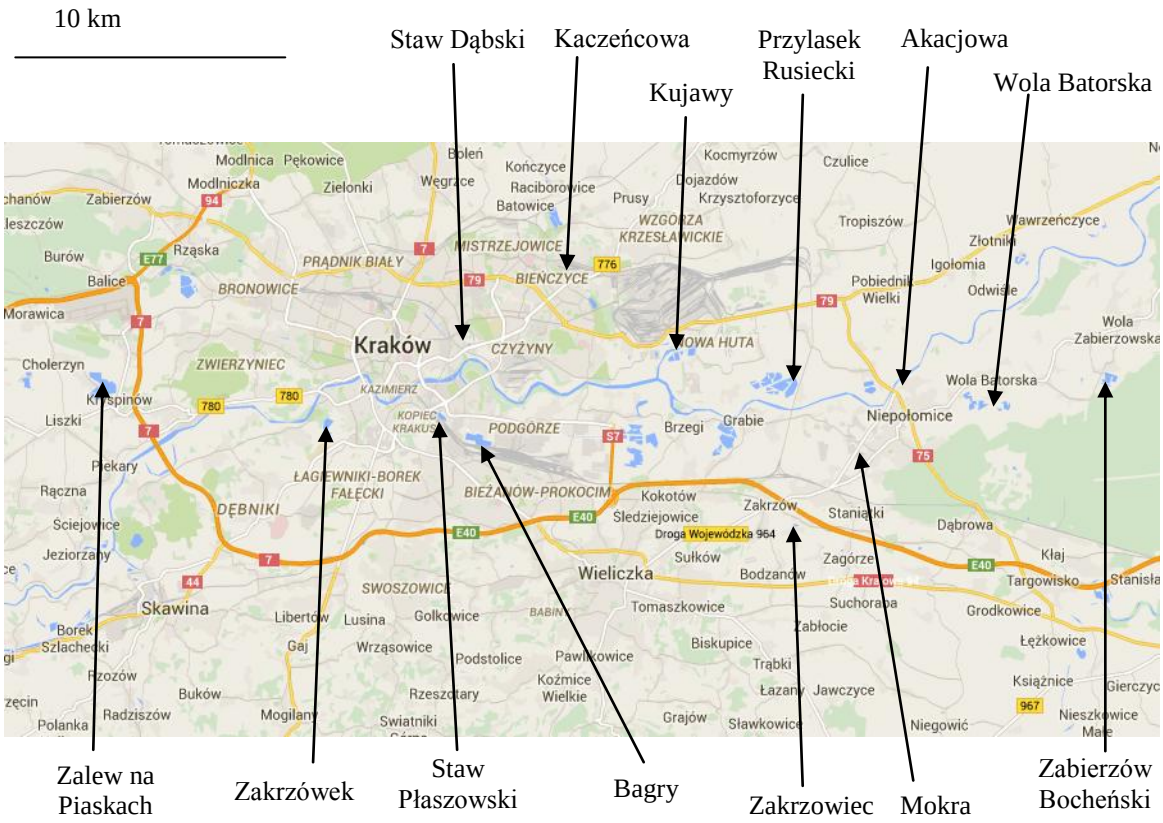

Figure 1. The study area.

Figure 2. The example of vegetation – the area near the Płaszów Pond. On the right-hand side – *Solidago* sp. Photo by A. Wagner.

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Developing Environmental Responsibility Through Place-based Education

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Abstract— **In response to the release of the Intergovernmental Panel on Climate Change (IPCC) *Fifth Assessment Synthesis Report*, Dr. John P. Holdren, Director of the U.S. White House Office of Science & Technology Policy stated "The IPCC's new Synthesis Report is yet another wake-up call to the global community that we must act together swiftly and aggressively in order to stem climate change and avoid its worst impacts". Realizing this call to action will require the active participation of governments, industries and global populations. Unfortunately governments and industries often let short-term economic considerations govern their behaviors contrary to the efforts required to address long-term environmental and social issues associated with climate change. Communities, NGOs, families and schools often lead the way in the development of informed populations whose citizens are supported in their personal responsibility for social actions towards climate change. Schools that follow place-based educational principles actively involve students in a range of community concerns with goals of informing and encouraging action in a wide variety of environmental and social issues. Research identifying long-term development of responsible citizenship is linked to place-based education. This paper describes long-term analysis of a program utilizing place-based science education and how these practices have effected the students' perceptions of their social and environmental responsibilities as citizens. It then explores how these approaches have led to responsible citizenship in northern Canada.**

Keywords- Place-based Education; Social Responsibility; Environmental Stewardship; Critical Pedagogy; Active Citizenship.

I. INTRODUCTION

The *Sixth International Conference on Bioenvironment, Biodiversity and Renewable Energie*s provides opportunities to address a wide range of topics relating humans and their interactions with the natural world. Most recently, the United Nations Intergovernmental Panel on Climate Change IPCC released the first of four chapters of its *Fifth Assessment Report* AR5 in November [1]. The report calls for a strong, concerted global effort to combat climate change. This is seen as necessary to protect the health of our economies, communities, children and future [2]. Such a concerted global effort will require that populations are informed, critical and actively involved in a wide range of climate related issues. In North America, various governmental, industrial and economic forces have strenuously opposed such action out of concern that these efforts may negatively impact their own economic wellbeing. Canadian Prime Minister, Stephen Harper characterizes this ideology as he recently stated, "No matter what they say, no country is going to take actions that are going to deliberately destroy jobs and growth in their country. We (Canada) are just a little more frank about that" [3]. Some governments and industry groups have undertaken aggressive, pervasive, and persuasive advertising programs in an attempt to assuage environmental concerns. A pro-development campaign within Canada has not gone unnoticed: "Responsible resource development, Canadians now accept, is something we cannot afford. The mantra of economic growth at any cost has made us willing participants in the rape that Harper and his corporate masters have enabled" [4]. Many resource development groups, along with political representatives, often distort and manipulate conditions so as make critical analysis undesirable and label those dissenters as 'radical' and 'unpatriotic'. A common narrative that has emerged in Canada is that citizens who express concerns about environmental conditions are often labeled 'extremists' [5]. Currently, numerous social media platforms consistently include rhetoric attempting to persuade Canadian citizens that pipelines, fracking and the Alberta tar sands bitumen development benefit the whole Canadian population through 'job creation' and 'national prosperity', with little to no reference to the cost to environments, health and to the social fabric of communities.

In the face of such public campaigns, it has become increasingly important to have an informed and critical citizenship prepared to embrace responsible environmental and social behaviors. Barr's research on environmental and social responsibility shows that public relations campaigns and advertisements are not sufficient to develop this type of citizenship [6]. This type of critical citizenship finds its origins rooted in active involvement at the level of community. Active citizens dynamically embrace the social responsibilities associated with environmental citizenship and see, as part of their civic roles, the necessity of becoming informed, maintaining critical perspectives and becoming actively involved in social, political and environmental issues [7]. The genesis' of such citizenship rests in family, community and schooling that promotes responsible environmental behaviors. Hines et al. in their study on the analysis and synthesis of research on environmental behavior determined the following variables were found to be associated with responsible environmental behaviors: knowledge of issues; knowledge of action strategies; locus of control, attitudes; verbal commitments, and; an individuals

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sense of responsibility [8]. A follow-up meta-analysis conducted by Bamberg and Möser twenty years later had similar findings. They found results that support "the conception of pro-environmental behavior as a mixture of self-interest and pro-social motives. … There is also progress in the understanding of factors/processes contributing to the development as well as activation of pro- environmental moral norms" [9, p. 22].

We posit that the conditions that give rise to responsible environmental and social behaviors are a major focus of place-based educational initiatives [10][11][12]. This paper explores the ways in which place-based initiatives may be incorporated in school instructional strategies. These place-based educational initiatives focus on the development of citizenship focusing on a critical knowledge of social, environmental and political issues and associated action strategies, locus of control, attitudes, verbal commitments and an individuals sense of responsibility within a community.

This paper is structured as follows: in Section II, we define citizenship and posit that critical thinking is a central foundation. In Section III, we introduce the field of place-based education. We proceed to describe two related longitudinal research projects (Section IV), and their methodologies (Section V), that examine the extent to which an experiential education initiative has fostered responsible citizenship through place-based activities. In Section VI, we discuss our findings, and finally, Section VII gives a summary of the main findings and highlights compelling evidence indicating that educational processes involving place-based activities that encourage data collection, refection and action are important antecedents to responsible citizenship.

II. CRITICAL PEDAGOGY AND CITIZENSHIP

Here, we use Glaser's definition of citizenship: "Good citizenship calls for the ability to think critically about issues concerning which there may be a difference of opinion and apply democratic values to the issues. Critical thinking has three components: an attitude of carefully considering problems, knowledge of logical inquiry methods, and skill in applying those methods". [13]

In the examination of the educational processes and social actions that lead to good citizenship, we posit that critical thinking is the central foundation [7][14][15].

> *Learning to think critically is conceptualized as the acquisition of the competence to participate critically in the communities and social practices of which a person is a member. If education is to further the critical competence of students, it must provide them with the opportunity at the level of the classroom and the school to observe, imitate and practice critical agency and to reflect upon it. Learning contexts must be chosen which students can make sense of and in which they can develop a feeling of responsibility for the quality of the practice in question.* [16, p. 359]

A crucial condition to critical pedagogy is it needs a context to be relevant and therefore be sustainable [15][17]. Community issues in which frame place-based learning provide the context for critical thinking, situational conditions, and for attributes such as locus of control. Place-based educational activities focus on environmental and social values, situational characteristics and psychological variables; as community action is open to a range of varying and competing interests [6].

III. PLACE-BASED EDUCATION

Place-based education (PBE) provides the learning context. PBE is an approach to teaching that is grounded in the context of community, both natural and social. It connects place with self and community. The field has emerged from the strong roots laid by thirty years of environmental education in North America [18][19]. PBE provides a purpose to the knowledge and reasoning taught in schools. It provides a contextual framework for much of the curriculum (i.e., gives meaning to the studies) and engages the student in the conditions of her/his own reality. Tyler examines an educator's ability to influence the environment to promote learning: "It is desirable that the problems be set up in the kind of environment in which such problems usually arise in life. This is more likely to result in his viewing this as a real problem worth of his effort to solve" [20, p. 69].

A survey of the literature on PBE reveals characteristic patterns to this still-evolving approach that make it distinctive:

- It emerges from the particular attributes of a place. The content is specific to the geography, ecology, sociology, politics, and other dynamics of that place. This fundamental characteristic establishes the foundation of the concept.
- It is inherently multidisciplinary.
- It is inherently experiential. In many programs this includes a participatory action or service-learning component; in fact, some advocates insist that action must be a component if ecological and cultural sustainability are to result.
- It is reflective of an educational philosophy that is broader than 'learn to earn'. Economics of place can be an area of study as a curriculum explores local industry and sustainability; however, all curricula and programs are designed for broader objectives.
- It connects place with self and community. Because of the ecological lens through which place-based curricula are envisioned, these connections are pervasive. These curricula include multigenerational and multicultural dimensions as they interface with community resources. [11]

IV. RESEARCH

We describe two related longitudinal research projects [21] that examine the extent to which an experiential education initiative has fostered responsible citizenship through place-based activities. The research project follows students from ten to twenty years following their participation in an integrated secondary science program

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focusing on place-based activities in which science data collection and peer-driven social, political and environmental actions are promoted. The Experiential Science Grade 11 (ES11) program was created as a pilot in 1994 and is now in existence as a territorial education model. The ES11 program is a Yukon Territory public-school program of studies open to all Grade 11 students. Students from a wide range of schools choose to take part in the program. Students spend 35-45 days of a 93-day semester conducting field studies related to community issues and strategically connected to integrated curriculum science-related studies. During a ten-year study period, 357 students have participated in the program and three different educators have taught the ES11 program. About two hundred place-based activities covering a wide variety of issues have been the focus of student learning over the decade of research.

The ES11 program integrates Biology 11 (a survey course including studies related to population ecology), Geography 12 (studies of Atmospheric dynamics, geomorphology and resource utilization), Chemistry 11 (introduction to quantitative chemistry), Art 11 (focused on scientific illustration and landscape), Field Methods 11 (applied studies in environmental monitoring protocols) and Physical Education 11 (focused on physical well-being and outdoor education). Students are engaged in two full-day labs a week (Chemistry and Biology), housed in the local post-secondary institution Yukon College. Field studies expose students to a wide variety of 'experts' associated with a range of resource management issues. Rigorous field methods, reliable well-kept data and valid scientific methodology are the foundation of the program. The GLOBE program (Global Learning and Observations to Benefit the Environment) is an instrumental educational platform utilized to assist in engaging ES11 students in the field of experiential science. GLOBE is a worldwide hands-on, school-based education program that was crafted to develop an awareness of one's "Place" in the natural world. Through the use of environmental science related activities and an integration of traditional ecological knowledge, students develop an enlightened recognition of the proper relationship of self, community and global world. Students collect field data and analyze various aspects of environmental study issues before developing strategies to address and take action related to community concerns.

During an ES11 semester, students take part in a wide variety of place-based activities, often in the company of scientists who have been working in a related field. They take part in an intensive month-long trip that involves field studies and community activities conducted in a range of settings. Most of the activities involve environmental monitoring and most are longitudinal in nature as they span over a period of years. The community issues students address during their time in the ES11 program are typically characterized as PBE initiatives. The ability to infuse an outdoor activity with related environmental field studies benefits the whole educational enterprise. The linking of environmental field studies with an outdoor pursuit gives both the study and the activity additional educational value and meaning. In addition, field studies reinforce both labs and lectures in specific subjects, addressing a traditional education problem: integrating theory and practice [22]. Courses such as geography, survey biology, quantitative chemistry, ecology and environmental studies are often integrated and lend themselves to field studies that link to a range of outdoor activities. The field studies approach often takes on the mantel of PBE since many of the field studies are centered on responding to community concerns, studying and collecting data and proposing possible responses to the community-defined problem. Addressing 'real' topics and finding ways to apply the prescribed learning outcomes to these studies have proven to engage students in ways that secure knowledge and strengthen positive community attitudes. In this respect, including field studies with outdoor pursuits has been proven to be a successful educational approach [19][23][24].

V. METHODOLOGY

This longitudinal mixed-methods research [25] examines the extent to which various educational strategies foster long-term commitments to responsible citizenship. The research followed two distinct yet related paths. The first was a tracking of the post-secondary educational activities of the students who took part in the ES11 program. We were able to compile information related to students' choices of post-secondary institutions, program of studies, course results and employment. The preliminary results of an initial survey, combined with interviews and anecdotal discussions with many of the former students pointed to the value of early student involvement in place-based activities leading to social and environmental action and responsibility. We conducted "a spiral of cycles" [26] in our research, thus the preliminary results allowed us to refine not only the questions, but also the research techniques for following surveys and interviews. This gave rise to the second stream of research designed to collect more detailed information about the choices and actions of this cohort of students and how their ES11 experience may have influenced their subsequent values and actions. To this end, an intensive survey addressing many topics including questions related to their values and actions associated to active citizenship were distributed to students of this cohort. At present both of these research projects are ongoing. This paper reports on our preliminary findings.

Many features of this research are possible because of the size and nature of the community. The city of Whitehorse, in the Yukon Territory, Canada, is a relatively small isolated northern city. Many students opt to carry on their post-secondary education in different 'southern' universities and technology institutions. The Yukon Government offers students, who complete their secondary school (Grade 7-12) in the Yukon Territory, a *Yukon Student Grant*. This grant provides each student $5500 each year over five years towards post-secondary education. Students are required to maintain and report their academic standing to qualify for the ongoing grants. Our research has been able to use these features to track and keep in touch with former ES11 students. Based on the relatively small size of the Whitehorse community (approx. population 20,000), personal,

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community and educational relationships that develop during the program's field studies and place-based activities give rise to frequent encounters with former students and /or their family in various environments. These conditions result in opportunities to engage with students and collect valuable data. Research information related to the students' post-secondary education gained during the formal and in-formal student interactions are recorded in a database of student post-secondary records. Records of students receiving the *Yukon Student Grant* are also used to contribute to this database. To date, 150 of the 357 students have been added to the post-secondary database. Of these, 37 out of 45 have submitted completed surveys. The detailed survey takes more than an hour to complete. Some students have chosen to complete the survey through a personal face-to-face interview process.

VI. PRELIMINARY FINDINGS

A. Post-Secondary Educational Pathways

The initial stage of research followed 150 former students. In a number of cases, the students followed more than one path. Since the *Yukon Student Grant* program is provided within the registered five years, information following the five years has been obtained through interviews of students within the cohort.

The previous tables tell only part of a 'story' related to the activities undertaken by this student cohort. In depth review of results show that 90% of the ES11 students tracked, to date, went to university. Of these, the greatest number followed a science program. More than half of these pursued fields related to environmental studies.

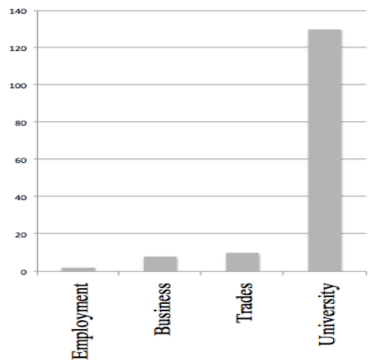

Figure 1. Post-Secondary Choices

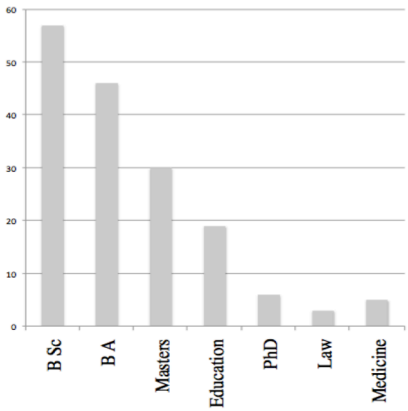

Figure 2. University Program Selections

B. Citizenship Survey Results

The second ongoing research project, that includes the intensive survey, paints a more comprehensive understanding of the impact the program had on long-term student engagement and citizenship. To date, 37 of 45 surveys have been returned. The detailed survey includes a bank of open-ended questions that address seven broad topics: education and training following high school; employment history; service to community or society; friendships persisting from high school; personal background; travel and recreational interests; impacts of high school on subsequent choices, and; a concluding open ended section that invites further comments. The first four banks of questions provide quantitative information while the last three banks of questions provides qualitative information. Overall, the intensive survey provides a blend of quantitative and qualitative information that yields insights into the individuals' citizenship and the extent to which the ES11 program may have influenced subsequent life choices. Each of these topics is summarized below.

1) Interim Quantitative Findings

a) Post-Secondary Education

- All 37 respondents took part in post-secondary education and training.
- All completed more than one program of studies and completed more than one degree.
- 25% attended their first course at the local post-secondary institution-Yukon College and then went to southern Canadian post-secondary institutions.
- 20% have attended university and training institutions in other countries (UK, US, NZ and Australia).
- 45% of respondents have completed graduate studies-Masters, PhD or professional degrees.

b) Employment

- Employment histories indicate that 85% of the students worked part-time in the Yukon during their time at studies and then took jobs in many different Canadian and international locations.
- All respondents had jobs when they responded, and 20% indicated they were looking for other positions.
- The most interesting result as it relates to this paper is 45% held employment in fields related to environment or environmental monitoring.

c) Travel and Recreational Interests

- All respondents have traveled to 2 or more continents and all indicate an interest in more travel.

They have collectively visited and/or worked in every continent.

- All respondents have remained active in outdoor activities and attribute many of their secondary school activities as the origins of these pursuits.
- 40% of the respondents indicate they coach in areas related to their outdoor interests.
- Some respondents listed a wide variety of outdoor activities while others describe their interests as outdoor activities and healthy lifestyles.

d) Personal Background

- 70% of the respondents indicated they were married or in long-term relationships, 55% have children and only 25% indicated they were single. Only one respondent had been divorced after six years of marriage.
- 60% considered themselves to be settled in their lifestyle, but of these, half indicated they were settled in their personal lives but not yet settled in their employment and also on where they live geographically.
- 25% of respondents live in the Yukon, and 60% of the respondents living outside the Yukon indicated they would like to live in the Yukon or in the province of British Columbia (just south of the Yukon).

2) Interim Qualitative Findings

To best represent the qualitative findings, we have chosen in this section of the analysis to provide representative quotes from the student responses that demonstrate key themes. Their voice, expressing common themes over a period of years, time and again provides compelling evidence regarding the values and subsequent actions of the former students.

a) Impacts of Experiential Science on Subsequent Choices

Three quarters, 75% of the respondents indicated that the ES11 program impacted their subsequent career and educational choices. The following quotes represent the scope of these views.

> *The extended trip in ES was an invaluable learning experience for me regarding my ability to interact and communicate with others. As we (students) were tangled in socially intense learning environments (due to traveling with many adolescents), we were forced to learn and adapt to other peoples behavior. My ability to communicate has continued to grow and is an integral part of my job. I started learning about tolerance, empathy, charity, and patience when I was in ES, and it has allowed me to grow into the medical provider that I am today.* (Male, 1998)

> *Motivated, engaged and challenging teachers with an awareness of current events reinforced my interest in global politics encouraged my interest in development studies and sustainable communities…it had a lasting impact on my decision to pursue an education that included an environmental component.* (Female, 1996)

> *From the ES experience, I value opportunities to learn through practical experience and trying –and possibly failing. I value innovation. I value environmental sustainability and policy decisions that have been informed by science.* (Male 1997*)*

> *Collecting salt from the side of the Alaska Hwy and taking it into the chemistry lab at Yukon College and actually figuring out how much salt was present in the gravel to link to caribou occurrences there, integrating chemistry, biology, and ecology. This experience as holistic learning changed how I viewed education and the world around me. I also learned that education could be fun and if I found something I enjoyed learning about, like how humans encounter their environment, it was up to me to figure it out for myself.* (Female, 2003)

> *My high school experience cemented my interest in natural sciences. I sought out programs that could offer field-based studies.* (Male, 1996)

> *My educational experience shaped my long-term employment goal to be part of an organization that promotes global sustainability, environmental awareness and social conscience while building networks between governments and civil society. Ultimately, it reinforced my interest in development studies with a focus on environmental issues.* (Female, 1999*)*

b) Relationships

It is important to reiterate that students who took part in ES came from different schools and different communities. Even though they were only together as a cohort for a four-month semester and many now live in different parts of the word, 60% of respondents indicated they remain in contact with friends they formed during the time they spent in ES11.

> *I have maintained friendships with some people that I only met through this program and would have otherwise not know. Although not all people I kept in contact with, there are a select few that our relationship has grown over the years and I talk to on a regular basis (despite our geographical differences).* (Male, 1997)

> *I am very close to a few of the people from my ES class, and continue significant relationships with them to this day. It is always a pleasure to see people from my ES class.* (Male, 2001)

c) Service to Community or Society

95% of the respondents indicated they participate in service for their community and/or humanity. The following two quotes give a sense of his commitment to service and how service is related to citizenship.

> *Volunteer service is an essential aspect of being part of a community. It is an important consideration in how someone chooses to live because to be a volunteer encourages people to pursue activities they are passionate about; it also encourages people to be increasingly aware of issues outside their own social circles; and provides the opportunity to foster attributes like commitment and dedication. With such attributes, volunteers ensure sustainable programs that address*

local issues and needs. I helped the Conservation Society of Sierra Leone facilitate community outreach workshops to encourage increased awareness of environmental and conservation of natural resource issues. I organize and conduct rapid assessment surveys of coastal sea-turtle habitat and local fishing practices. (Female, 1999*)*

One of the things I learned from ES is that everyone has a voice; it's all about how you say what you want to say. One of the most important things is to learn about the matter yourself and not rely on what others (e.g., pamphlets, protestors, etc.) are trying to convince you of. Do your own research, learn about it and you will have a stronger voice for it. People are more likely to listen to a knowledgeable person than a passionate, one-sided rant. And you might learn something yourself that changes your view of what others are saying. Being open to other people's opinions is as much a part of having a voice as knowing what to say. (Male, 1998)

Only 2 of the respondents indicated their voices were not heard and had little opportunity to influence decisions locally or nationally. A number of respondents spoke to problems with electoral systems but they still felt the capacity to influence change. Every participant responded that they vote in civic, territorial, provincial and/or national elections. This contrasts with the turnout of average Canadians as reported in the most recent National May 2011 election; only 39% of Canadians aged 18-24 years and 45% aged 25-34 years voted [27].

d) Open-Ended Section

The survey invited respondent to make comments in an open-ended format. The following are a representative sample of their comments. Most of these relate to the experiential and PBE process:

After being in ES and after having gone through a moderate amount of post-secondary education I think that experiential learning is a more robust way of learning and teaching. Being able to see a medial moraine, a U-shaped valley, the impacts of clear cutting, etc., turned 'learning objectives' into concrete lessons. I think that in a perfect world all curriculums should/would be delivered in the same manner: intensive, tactile and above all meaningful. (Male, 2004)

Innovative experiential programs like these are an excellent model and should be expanded into other regions of Canada and other subject areas – perhaps in physics (engineering) and political/social studies? Decisions on where to move with my family and where to enroll my child for school will be heavily influenced by the availability of programs such as ES. (Female, 1995)

VII. CONCLUSION

The extent and nature of the responses to the detailed survey shows a community of practice [28] of young adults involved in community and a heightened understanding of 'place' in active ways. They express the significant role this type of educational experience has influenced subsequent life choices. Most participating students felt a sense of social and environmental responsibility, we suggest are values and attitudes needed to address issues such as climate change.

Data from the quantitative and qualitative analysis show complementary results. Those participating in the ES11 program demonstrated an uncommon level of engagement and civic and environmental responsibility. These students refer to the challenging and significant place-based field studies, the co-operative work relationships that develop during their semester and diverse instructional processes used throughout the program as features that left lasting change. Field studies resonated with those students who learn best experientially and in social contexts. Students consistently reported the short and long term benefits attributed to their participation. A number of students indicated they struggled with conventional classes yet found success and engagement in the environmental field studies approach to courses. In terms of conventional academic scores, students in ES11 consistently outscored all other high school classes taking similar courses.

The development of citizens who internalize community and global challenges related to social and environmental goals appears to be an essential aspect of addressing phenomena related to climate change. This research sheds light on how public schooling may contribute to such development. In summary, the actions and values expressed by ES11 participants reflect those qualities of responsible citizenship needed to address the challenges identified by the IPCC *Fifth Assessment Report* [1]. This research provides compelling quantitative and qualitative evidence indicating that educational processes involving place-based activities that encourage data collection, refection and action are important antecedents to responsible citizenship.

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A Naturalistic Indicator of the Forest Quality and its Relationship with the Land Use Anthropentropy Factor

Theory, Tools, and Results for an Italian Case Study

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***Abstract*— This paper describes a new indicator related to an important aspect of the forest landscape: the quality, expressed by the forest floristic composition, according to the phytosociological approach. Furthermore, the relationship with an existing land use indicator, the Anthropentropy Factor, is investigated. Another novelty of this research is its multidisciplinary approach: we combine the classical algorithms of computer vision systems to process the images from GIS (Geographic Information System) databases with the necessary expertise provided by the biological knowledge. The goal is to build a deep knowledge about some aspects of biodiversity preservation, by studying the impact of anthropic activities, both inside (urbanization) and outside (forests) the areas occupied by human settlements. We define two metrics to classify the levels of land use and forest quality status. The knowledge coming from the computation of the two indicators and the corresponding metrics can be used for policy actions, to guide local government decisions for biodiversity conservation in the landscape planning. The two indicators and the methodological approach are validated by presenting experimental results on a case study of a North-West area of Italy.**

Keywords- biodiversity; land use; environmental indicator; forest status; Anthropentropy Factor.

I. INTRODUCTION

Land use estimation is a key aspect for biodiversity preservation; in fact, the European Environment Agency considers land use and biodiversity in the same policy target and objective for the next decades [1]. The reason is the well-known significant loss of the territory, both for vegetal and animal species, due to the impact of anthropic activities on the environment. There are plenty of examples of human activities which lead to soil sealing and loss of wild nature: urban and rural expansion, new roads and communication lines, settlements for industries, tourism and services, and intensive farming.

If we consider the problem by a quantitative, absolute, point of view, the situation may not seem so dramatic: according to the most recent Corine Land Cover data [2] referring to the period 2000-2006, the artificial areas cover only the 4% of the land in Europe, as compared to a 34% of forests, a global value of 51% for activities to support the economic growth and food (agriculture, crops, pasture and semi-natural vegetation) and a 11% of bare soils, water and wet lands. However, if we consider the net change in land cover, expressed as a percentage of the initial year (2000), we observe a worrying value of +2.5% for the artificial areas, while other typologies of land cover have important decreases or slight increases (less than 0.5%).

Processes which cause land-use change are different in different parts of Europe [3]: the Boreal and Alpine regions are dominated by forest management; abandonment and intensification are mainly encountered in the Mediterranean; urbanization and drainage are more characteristic of the Continental and Atlantic regions. In Italy and, particularly, in the studied area, urbanization and agricultural intensification are the main drivers of biodiversity loss in the planar belt, while land abandonment and the consequent forest re-colonization cause biodiversity loss in the hilly-montane belt [4]-[6].

For all these reasons, a high challenging goal of the scientific community is to provide efficient ways to define, measure and correlate indicators which refer to some aspects of land use and biodiversity estimation, in order to help in defining policies to preserve environment and, in the same time, to assure a sustainable growth of our economies and societies. This ambitious goal is the main aspect of the research described in this paper, which is organized as follows. Section II describes the addressed problem and main novelties of our approach. Section III describes the state of the art, for what concerns the problem of defining efficient indicators for land use and forest status. Section IV addresses the problem of computing the new proposed Forest Status Quality Indicator (FSQ), and its relationship to a land use indicator, which has been recently proposed in literature, i.e., the Anthropentropy Factor, (AF). Section V describes the results of the computations of the new indicator on a real case on the Italian territory. Conclusion and considerations about future work close the article.

II. OUR MULTIDISCIPINARY APPROACH

One of the main novelties of the proposed study is its multidisciplinary approach, which bridges across two important fields of our modern scientific research: computer science and botany. Both of them have knowledge, tools and paradigms which are able to assess the impact of human activities for a sustainable future. In particular, we have chosen to address the problem of estimating land use and,

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among the different categories of land use, to pay attention to two main aspects:

- The estimation of the areas which are not influenced by anthropic activities and, potentially, could be occupied entirely by wild nature;
- Inside these areas, which parts are occupied by forests, and their *quality status*.

We have chosen these two aspects because (a) the first is essential to estimate, for a given territory, which parts are yet available for wild habitats, and (b) the second takes into consideration the important presence of the forests which provide benefits for the human well-being (the so-called ecosystem services), such as flood prevention, erosion control, CO_2 absorption, climate regulation, *refugium* function for wild plants and animals, recreation, science and education. However, a simple counts of square kilometers is a too rough method to give hints on the real status of the environment for biodiversity preservation. In fact, others elements have to be taken into consideration, in order to describe the two aspects by indicators which have a real meaning, from an ecological point of view. In particular, we fixed these goals:

- The proposed indicators have to take into account not only the areas, but also their shapes, as fragmentation of habitats is a great problem for biodiversity preservation.
- The presence of a forest, inside a territory, has to be described not only by its relative area, but also by several aspects related to its quality, as the number of alien or protected species and the stratification.

Our multidisciplinary approach combines algorithms of computer-assisted image processing and remote sensing data analysis with the knowledge about forest typologies based on their floristic composition according to the phytosociological approach [7-10]. Besides the indicators, we propose two metrics to define ranges of increasing worrying status for biodiversity preservation. Such metrics may support policies for management and restoration of forests and landscape.

III. THE STATE OF THE ART

A. Forest quality indicators

Quality means different things to different people. The assessment of forest quality differs according to the different components that can be evaluated (ecological, social and/or economic components associated to forests). In many assessment systems, environment has been relegated to a relatively unimportant element, if compared with other issues such as economic importance, although there are now also some specialized indicator sets relating to the environment, such as WWF (World Wide Fund For Nature) Living Planet Index [11]. Other examples include: the IUCN (International Union for the Conservation of Nature) well-being index [12], that divides indicators into two classes, the first relating to human well-being (socio-economic) and the second to the environment (ecological, environmental services etc.) and the Montreal Process criteria and indicators [13], for temperate and boreal species outside Europe, which uses seven criteria (and 67 indicators) including the conservation of biological diversity.

B. Land use indicators

All data provided by international projects [14] proves that our high-energy consumption lifestyles are exerting an increasing, destroying pressure on wildlife habitats. We have to consider not only the soil sealing phenomenon, i.e., thousands of hectares/year are covered by concrete, but also the fragmentation of territory and of habitats, a serious threat for most of endangered species in Europe. Therefore, conventional land use indicators based on the simple computation of area percentage are not able to express the gravity of the problem. For this reason, we have considered recent contributions in literature [15-16], which describe a new indicator, called Antropentropy Factor (AF). Here, we recall the basic definition and concepts which are essential to understand the relationship between this indicator and the Forest Status Quality Indicator here proposed (for details on the properties of the AF indicator and its application to Italian territory, see [15]).

Anthropentropy is a neologism, from the Greek term *Anthropos* (*Ἀνθρωπος*) = man, and *entropy*; in fact, the AF indicator wants to express the "disorder" introduced in natural ecosystems, by the presence and disturbance of human beings. The AF expresses in an absolute, continuous scale (from 0 to 1) the degree of anthropic human activities and the consequent land use. We think that this indicator is the closest one to a naturalistic evaluation of land use, because it does not only computed the percentage of land occupied by human activities and urban expansion, but also it takes into consideration the *shape* of the areas subtracted to nature, and their relative positions, thus incorporating an important aspect of fragmentation and its impact on biodiversity. This is possible because the computation is performed by using classical image processing morphological operator of dilation [17] on satellite GIS images of the territory on satellite maps of the territory.

In order to compute the AF indicator, we define the following entities: (a) the delimited part of a geographic territory under consideration, and its area S, in squared kilometers; (b) the Death Zone, as the union of all the anthropic regions of the territory, and its area DA, in square kilometers), and (c) the Neutral region as the part of the territory, if any, containing inland waters, (e.g., lakes or lagoons) and lands located more than 3,000 m above sea level, and its area NA (in square kilometers). The Anthropentropy Factor (AF) is defined [15] as the ratio:

$$AF = DA / (S - NA) \quad (1)$$

The AF expresses the land use as a fractional number, between 0 (completely uninhabited territory, DA = 0) and 1 (the Death Zone completely occupies the territory, but for the Neutral Zone (if any, because in the Neutral Zone human settlements are not possible.) In Table I, the corresponding metric on the AF indicator is described. For a reasoned treatment of the metric and its relationship with a possible policy making for a sustainable development, see [15-16].

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TABLE I. THE METRIC ON THE AF INDICATOR FOR LAND USE.

Class of land use and map color	Evaluation of Land Use	
	Intervals of AF	***Meaning***
1 light green	0 <= AF <= 0.2	Very low level of anthropentropy, *ideal* situation for nature and human beings
2 green	0.2 < AF <= 0.4	A first worrying level of anthropentropy, but the situation is still *good*
3 yellow	0.4 < AF <= 0.6	A serious level of anthropentropy, with a beginning negative impact of anthopization on the environment.
4 red, light violet	0.6 < AF <= 0.8	A very serious level of anthropentropy, with a great negative impact of anthopization on the environment.
5 violet, black	0.8 < AF <= 1	The worst situation, with an irreversible environmental degradation.

In Figure 1, the map of the area of our case study (the territory of Pavia province) is shown: for each municipality, its territory is depicted in a color related to the class of land use, as specified in Table I (from green, yellow, red and black). Even if the AF indicator is able to take into considerations quantitative extensions, shapes and relative positions of the anthrophized areas of a territory, it expresses only the land use pressure on the environment (according to the DPSIR (Driving Forces, Pressures, States, Impacts, Responses) model [18] of the European Environment Agency); it does not give any hints on the state of the green areas *outside* the urbanized areas, which is the goal of the second and new indicator here described.

IV. THE FOREST STATUS QUALITY INDICATOR

For our purposes, we define the forest quality status as the value of its ecological components, with particularly reference to the biodiversity conservation. We have chosen the following components: the number of forest layers (more layers correspond to higher biodiversity), the presence of protected species according to the regional law (more protected species mean higher and better biodiversity) [L.R. 10/2008] and the presence of alien species (lesser alien species mean higher and better biodiversity). We considered only natural forests (plantations were not taken into consideration). Furthermore, we considered only forests occurring on areas greater than 10.000 square meters. In forest patches smaller than 1 ha, floristic richness is generally very low [19]. For a given territory of area S, we define a set of sub-regions occupied by natural forest F_i (i = 1, 2, n). Each of F_i may have one or more occurrences, denoted by the index k, in the territory (k = 1, 2, max(i)). Each k-th occurrence is characterizes by: (a) an area A^k_i, expressed in square meters, for i= 1,2,,…n and k = 1, 2,… max(i) and (b) a type of T_i, derived from the GIS Database "Map of the Forest Types of Lombardy" [20], which classifies forests on the basis of their physiognomy (dominant woody species) and the ecological characteristics of the site where they occur (geological substrate, type of soil, etc.) [21].

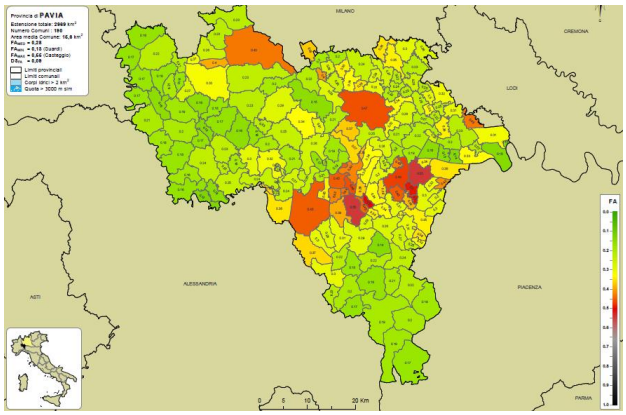

Figure 1. The visual map for the AF land use indicator for the municipalities of the target area of our case study (Pavia Province, Lombardia, North Western Italy).

In our target territory, we have 66 different forest types, but only 32 of them have occurrences whose areas are greater than 10.000 square meters. Therefore, in our case study, n= 32.

For each forest T_i, we found the correspondence with one or more phytosociological tables [22]. When this correspondence was not reported by the above mentioned authors, we used other bibliographic references or phytosociological relevés collected in the area where the forest type occurs. In Table II, a list of the types T_i and the relative reference *syntaxa*, for the territory under investigation, is provided. The Type Lab field in the Table is a label which refers to the database [20] used as input data source.

For each forest type T_i, which is described by one or more phytosociological tables, we defined a set of the three indicator components (s_i, a_i, p_i) above described:

- Stratification (number of layers) of a forest type i (s_i): this component analyzes the quality of the forest structure. The tree and the herb layers are always present in a forest. The shrub layers (high-shrub and/or low-shrub layers) were considered valuable if their total cover were > of 10% of the sampled forest area (indicated in the phytosociological tables) or at least one species presented an abundance value equal to 2.
- Percentage frequency of alien species (a_i) in the corresponding phytosociological table/s. When more phytosociological tables described a forest type T_i, a mean value between the percentages of each table was calculated.
- Percentage frequency of protected species (p_i) in the corresponding phytosociological table/s. When more phytosociological tables described a forest type T_i, a mean value between the percentages of each table was calculated.

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TABLE II. FOREST TYPES FOR THE PROVINCE OF PAVIA (ITALY)

Type Lab[a]	Description of forest types T_i and relative reference *syntaxa*
1	T_1: Oak-Hornbeam wood of the lowlands *Syntaxa: Polygonato multiflori-Quercetum roboris* subass. *carpinetosum* and *anemonetosum* Sartori 1984; *Quercus robur*, *Carpinus betulus* and *Physospermum cornubiense* community; *Quercus robur*, *Carpinus betulus* and *Holcus mollis* community
12	T_2: Oak wood of inland sand dunes ("dossi") *Syntaxa: Quercus robur* community
13	T_3: Oak wood of stony river beds *Syntaxa: Quercus robur* and *Brachypodium rupestre* community
14-15	T_4, T_5: Oak-Elm wood (also including the Black Alder variant) *Syntaxa: Polygonato multiflori-Quercetum roboris* subass. *ulmetosum* Sartori 1984
20, 23	T_6, T_7: *Quercus pubescens* wood of the carbonatic substrates (also including the Chestnut variant) *Syntaxa: Quercus pubescens*, *Euphorbia cyparissias* and *Epipactis helleborine* community
26, 27	T_8, T_9: *Quercus petraea* wood of the carbonatic substrates and mesic soils (also including the Chestnut variant) *Syntaxa: Physospermo cornubiensis-Quercetum petraeae* Oberd. et Hofm. 1967
28	T_{10}: *Quercus cerris* wood *Syntaxa: Quercus cerris*, *Cruciata glabra* and *Anemone trifolia* community
45, 48, 49, 50, 57	T_{11}, T_{12}, T_{13}, T_{14}, and T_{15}: Chestnut wood on drift; Chestnut wood of the carbonatic substrates (mesic soils, meso-xeric soils, xeric soils); Chestnut wood of the siliceous substrates and mesic soils *Syntaxa: Physospermo cornubiensis-Quercetum petraeae* Oberd.et Hofm. 1967*; Castanea sativa* and *Corylus avellana* community
63, 64, 65	T_{16}, T_{17}, and T_{18} *Ostrya carpinifolia* and *Fraxinus ornus* wood (of layer, of cliff, typical) *Syntaxa: Knautio drymeiae-Ostryetum* Mondino et al. 1993
84	T_{19}: Birch wood *Syntaxa: Betula pendula* community
88	T_{20}: Primitive Beech wood *Syntaxa: Trochiscantho-Fagetum* Gentile 1974; *Fagus sylvatica* and *Acer opulifolium* community
89, 96, 97, 105	T_{21}, T_{22}, T_{23}, and T_{24}: Beech wood of the carbonatic substrates (high-montane, montane, montane of xeric soils, submontane) *Syntaxa: Trochiscantho-Fagetum* Gentile 1974; *Fagus sylvatica* and *Acer opulifolium* community
99	T_{25}: Beech wood of the siliceous substrates *Syntaxa: Trochiscantho-Fagetum* Gentile 1974; *Fagus sylvatica* and *Acer opulifolium* community
172	T_{26}: Black Alder wood of gulley *Syntaxa: Alnus glutinosa*, *Populus alba* and *Ulmus minor* community
173	T_{27}: Typical Black Alder wood *Syntaxa: Osmundo regalis-Alnetum glutinosae* Vanden Berghen 1971; *Carici elongatae-Alnetum glutinosae* W. Koch 1926 et R. Tx. 1931; *Carici acutiformis-Alnetum glutinosae* Scamoni 1935
177	T_{28}: Willow wood of bank *Syntaxa: Salix alba* community*; Salicetum albae* Issler 1926
180	T_{29}: *Salix cinerea* wood *Syntaxa: Salicetum cinereae* Zolyomi 1931
183	T_{30}: White Poplar formation *Syntaxa: Populus alba* community
188	T_{31}: Pure *Robinia pseudoacacia* wood *Syntaxa: Robinia pseudoacacia* community
189	T_{32}: Mixed *Robinia pseudoacacia* wood *Syntaxa:Robinia pseudoacacia*, *Quercus robur* and *Ulmus minor* community

a. According to ERSAF database [20]

The three components can assume only discrete values, from 0 to 3. While the definition of quality of stratification is independent on the altitude of the forest, the definition of values related to the percentages of alien and protected species is different, according to the altitude. Thus, naturalness is higher in the montane belt than in planar belt. We differentiate between forest types belonging to the class "high hilly and montane" (altitude > = 500 m) and forest types belonging to the class "planar and low hilly" (altitude < 500 m). The three components (s_i, a_i, p_i) are defined according to an empirical if – then- else algorithm, reported in Figure 2.

If the number of layers = 2 , then $s_i = 1$
Else if number of layers = 3 , then $s_i = 2$
Else if number of layers = 4 , then $s_i = 3$

For altitude <500 m:
If the percentage of alien species is > 40 then $a_i = 0$
Else if alien species range is (15- 40] then $a_i = 1$
Else if alien species range is (5- 15] then $a_i = 2$
Else if alien species range is [0- 5] then $a_i = 3$
If percentage of protected species range is (0.5-3] then $p_i = 1$
Else if protected species range is (3- 6.5] then $p_i = 2$
Else if protected species range is > 6.5 then $p_i = 3$

For altitude > = 500 m:
If the percentage of alien species is > 10 then $a_i = 0$
Else if alien species range is (5-10] then $a_i = 1$
Else if alien species range is (2-5] then $a_i = 2$
Else if alien species range is [0- 2] then $a_i = 3$
If percentage of protected species range is (0.5-5] then $p_i = 1$
Else if protected species range is (5- 10] then $p_i = 2$
Else if protected species range is > 10 then $p_i = 3$

Figure 2. The computation algorithm of the three indicator components.

For each of the forest type i of Table II, we computed the relative value set of (s_i, a_i, p_i), according to the algorithm of Figure 2 and the phytosociological tables and/or relevés: the complete value set is reported in Table III.

TABLE III. THE VALUE SET OF COMPONENTS FOR STRATIFICATION, ALIEN AND PROTECTED SPECIES, FOR EACH FOREST TYPE.

Type Lab	Components (s_i, a_i, p_i)
1	3,2,3
12	2,2,1
13	3,3,3
14-15	3,2,2
20, 23	3,3,1
26, 27	2,3,3
28	3,3,2
45, 48, 49, 50, 57	2,3,3
63, 64, 65	3,3,2
84	1,3,0
88	3,3,3
89, 96, 97, 105	3,3,3
99	3,3,3
172	3,3,1
173	2,3,2
177	1,1,0
180	2,2,0
183	3,1,0
188	2,1,0
189	3,2,0

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After determining the values of the set of components for stratification, alien and protected species, it is now possible to define the Forest Status Quality Indicator (FSQ) of a given territory as:

$$FSQ = \Sigma_i \ \Sigma_k \ (s_i + a_i + p_i)*A^k_i/S \qquad (2)$$

for i= 1, 2,.., n, k = 1,2,… max(i) where i is one of the n the significant forest type (at least one occurrence of the forest has A^k_i >= 10.000 square meters) which is present in the territory under investigation, A^k_i is the area of the k-th occurrence of forest type i, and S is the area of the territory. The number of occurrences may vary, from a minimum of 1 to a maximum, which depends of the forest type (max(i)).

The FSQ definition is the weighted values of the components, where the weights are the ratios between the areas of the forests and the area of the territory under investigation. The wider is the area occupied by a forest, the higher is its contribution to the global quality of the territory. Besides, its contribution is related to the values of the components (stratification, alien, and protected species) as described in the if-then-else algorithm. The summation in (2) is for all the forest types of the territory under investigation, and for all the occurrences of the forests.

The FSQ value can range from 0 (no forests are present in the territory with at least one occurrence of A^1_i> 10.000) to a maximum of 9, which is derived by considering the "perfect", quite unrealistic, situation of a forest of very high quality (set of components (s_i, a_i, p_i) =(3,3,3)), and where the areas of all the occurrences are equal to the area of the entire territory ($\Sigma_\iota \ \Sigma_\kappa \ A^k_i = S$).

By using an approach similar to the AF metric, we have defined a set of ranges for the FSQ indicator, starting from an unsatisfactory forest quality, a satisfactory but improvable situation, a good, an optimum situation and overbalanced situation. In Table IV, the metric for the FSQ indicator and the suggested policy actions are shown.

TABLE IV. THE METRIC ON THE FSQ INDICATOR FOR FOREST QUALITY.

Class of forest quality	**Evaluation of Forest quality and policy**	
	Intervals of FSQ	***Suggested policy***
1 Unsatisfactory	0 <= FSQ <= 0.9	Very low level forest quality. A high-impact policy of restoration and/or requalitication of forest is mandatory.
2 Satisfactory but improvable	0.9 < FSQ <= 1.8	Sufficient forest quality but improvable. A policy for forest biodiversity preservation is preferable.
3 Good	1.8 < FSQ <= 3.6	Good forest quality, the first level of satisfactory situation. A policy for the conservation of existing forests is suggested.
4 Optimum	3.6 < FSQ <= 4.5	The optimun situation, with a high quality of forests. A policy for the conservation of existing forests is suggested. Anyway, if shrublands and grasslands are scarse or absent, a policy for their biodiversity preservation has to be considered.
5 Overbalanced	FSQ > 4.5	The overbalanced situation, forests have overcome other ecosystems. A policy for shrubland and grassland biodiversity preservation is highly suggested.

V. EXPERIMENTAL RESULTS

A. Data Sets and computer-based processing

The case study is the province of Pavia (Figure 1), which is located around its chief town, Pavia (latitude, longitude: 45°11'7"44 N, 09°9'45"00 E), in the North-Western part of Italy. The province consists of 190 Municipalities, with the altitude (meters above sea level) in the range [53-951]. In order to compute the value of FSQ in (2), it is necessary to have a description of the territory in terms of administrative boundaries and area, the geo referential coordinates of the occurrences of the forest, and their relative types and areas. We have used two GIS databases in order to derive the useful data: (a) the database of the Italian administrative boundaries provided by Istat [23], where we can compute the exact boundaries of the municipalities of the case study and their relative areas (the term S in (1) and (2)), and (b) the ERSAF (Ente Regionale Servizi Agricoltura e Foreste, i.e., Regional Agency for Agriculture and Forest Services) database [20]. By superimposing the two data sets we can obtain a visual map of the territory, where, for each municipality, we can compute, with a standard primitives of GIS software, the areas of each k-th occurrence of each forest type i (the value A^k_i. in (2)).

Figure 3. The visual map of the input data [20]: different colors refers to the forest types of Table II (a detail of the province of Pavia, Italy).

In Figure 3, the visual map for a limited zone of the studied area is shown in the standard Google Earth interface. Different colors refer to different types of forests.

B. Results on the case study and discussion

The values of AF and FSQ computed, according to (1) and (2), for each municipality are shown in Figure 4. The correlation between the two sets of values is very low (correlation coefficient: -0,197651). The dispersion plot

(FSQ v. AF) of Figure 5 also shows that the two indicators are quite independent and this is a positive result, because it expresses the fact that the two indicators are related to independent and different pressures on the environment: land use and forest quality. Figure 5 also shows that all the Municipalities with serious levels of AF (> 0.4) have very low levels of forest quality (FSQ < 0.9). This underlines a worrying trend to neglect the ecological compensations to mitigate the impact for increasing urbanization. On the other side, some Municipalities of high altitude show very low levels of AF (< 0.2), but overbalanced levels of FSQ (> 4.5), underling a worrying trend to neglect the forest re-colonization caused by land abandonment. All the results indicate how environment and biodiversity loss are scarcely considered in the land use policies of the study area.

VI. CONCLUSION AND FUTURE WORK

In this paper, an innovative indicator for forest quality has been proposed and its relationship with the land use anthropentropy factor has been investigated. The forest quality indicator is coherent with literature indications [13] which suggest the use of existing database, indigenous knowledge and possibly some field research as methods for data collection in order to evaluate the biodiversity conservation. Furthermore, they also suggest basic biological knowledge (in our case, phytosociology) as necessary expertise.

Current and future developments of this work include: a wider study area (Lombardy Region) and a shape parameter related to forest occurrences. An interesting analysis is to investigate how to combine FSQ and AF in a "super-indicator".

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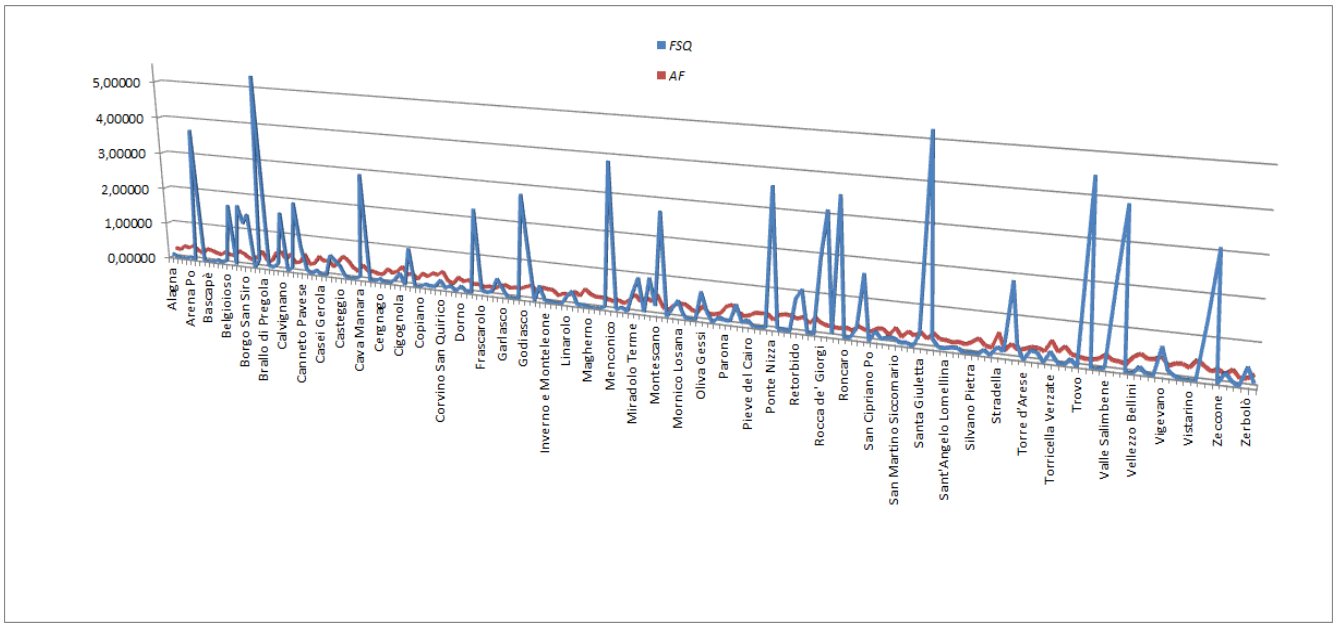

Figure 4. The two indicators Anthropentropy Factor (AF) and Forest Status Quality (FSQ), for all the municipalities of the province of Pavia.

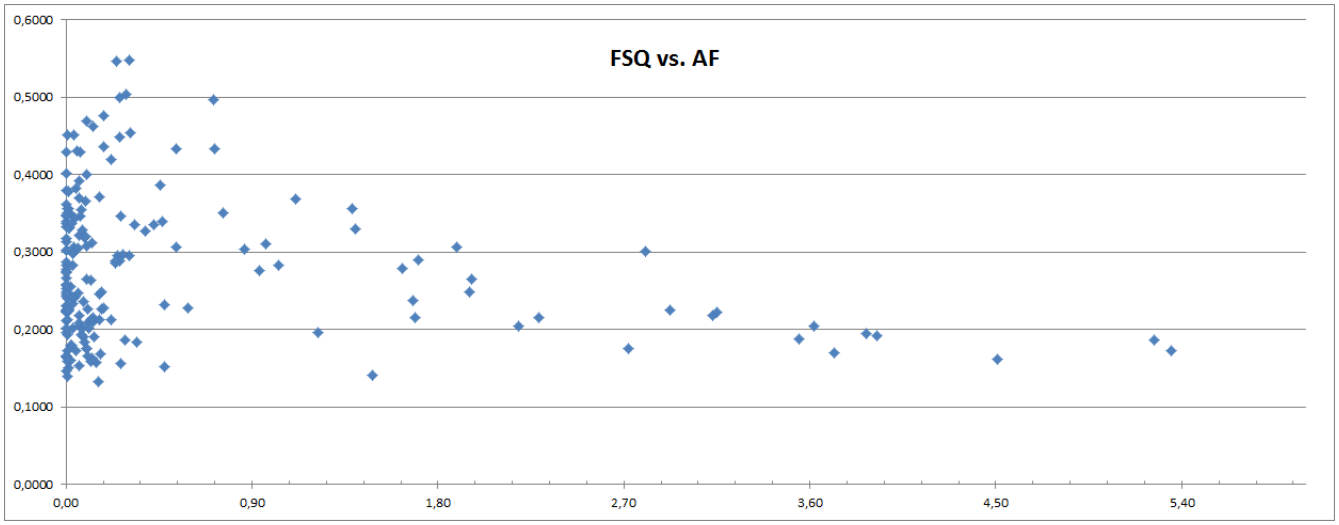

Figure 5. The relationship between the two indicators for land use and forest quality: dispersion plot of FSQ vs. AF, for all the municipalities of the province of Pavia.

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Assessment of Human Pressure on Forest Ecosystems in the Czech Republic

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***Abstract*— Forest ecosystems play an important role for natural environment as well as for human society. With population and economic growth forests are put under increasing pressure leading to destruction of habitats and irreversible biodiversity loss. Quantification and interpreting the degradation of forest ecosystems can help raise public and political awareness needed for preserving the remaining species. In this study, human pressure on forest ecosystems in the Czech Republic and its impact on biodiversity loss were assessed. One of the main tools used is Mean Species Abundance indicator assessing human-induced changes in biodiversity including land-cover change, land-use intensity and fragmentation. Results are supplemented by statistical outputs of the National Forest Inventory and the Databank of natural forests of the Czech Republic. The results show serious decrease of mean species abundance in all landscape including forests. Most of the forested areas in the Czech Republic are affected by long-term human influence resulting in significant biodiversity loss and forest degradation.**

Keywords-forest; human pressure; biodiversity; mean species abundance.

I. INTRODUCTION

In European landscape, forest ecosystems present an irreplaceable part of natural environment for habitat they provide, ability of climate regulation, flood and erosion control, water cycle and others including many services and products used directly by humans [1]. With growing population and demand for natural sources, forests are under increasing pressure. In the Czech Republic, an inland human-dominated Central European country with an area of approximately 79,000 km^2, forests currently cover 33 % of the area. Although forested areas have continuously expanded there since the end of 19th century, they suffer from pollution, fragmentation and unsustainable management [2].

In our ongoing research, the anthropogenic pressure on ecosystems in the Czech Republic and its impact on biodiversity loss are assessed. Forested area assessment is one of the key parts of the study as forest ecosystems represent most of natural preserved and protected areas in the Czech Republic. The aim of the work is to quantify the extent of anthropogenic pressures on ecosystems, assess their spatial patterns and compare impacts in forested area with other landscape.

Methods of the study are described in Section 2 of this paper, including specification of spatial datasets and indicator used for assessing biodiversity loss. In Section 3, first results are presented, followed by conclusion in Section 4.

II. METHODS

Main steps of this study were (1) creating datasets of spatial distribution of Mean Species Abundance indicator (MSA) in the Czech Republic as a measure of anthropogenic pressure, (2) comparing impacts in forested area with other landscape, (3) supplementing results by statistical outputs of the National Forest Inventory in the Czech Republic.

A. Spatial datasets

To calculate MSA values based on land use and land cover data, the Consolidated Layer of Ecosystems of the Czech Republic (CLES) [3] was used as the most detailed currently available dataset of ecosystem distribution on the national-wide level. CLES distinguish 41 categories of habitats on a fine spatial resolution, including information on the degree of naturalness for each habitat category. Where a clarification was needed, actual land cover was compared to original landscape using a map of potential natural vegetation in the Czech Republic [4]. Data and results were supplemented by statistical outputs of the National Forest Inventory in the Czech Republic [5] and the Databank of natural forests of the Czech Republic [6].

B. Mean Species Abundance

MSA is an indicator developed for model GLOBIO3 assessing human-induced changes in biodiversity based on simple cause-effect relationships between environmental drivers and biodiversity impacts [7]. Drivers considered in this study are land-cover change, land-use intensity and fragmentation as they are assumed to be the main cause for biodiversity loss [8][9]. MSA values indicate relative remaining mean species abundance of original species compared to primary vegetation scaled between zero and one (1 = all original species, 0 = no original species). Water surfaces are not evaluated in this version of MSA indicator [7].

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First step was assigning MSA impact values of land-cover change and land-use intensity to 41 CLES categories of habitats in the Czech Republic. Alkemade et al. [7] define 14 categories of land cover types and their MSA values based on a broad meta-analyses of available literature. Most of the CLES categories were assigned by their definition (artificial surfaces, natural vegetation) while several CLES categories were evaluated as intermediate and given a proportional value of two MSA categories following approach used by Prydatko et al. [10]. Geographical distribution of MSA values was then processed in GIS software. Another step was assessing fragmentation impact based on the extent of individual patches of forested areas based on approach of Alkemade et al. [7]. Neither distance nor shape of patches is considered in this version of MSA indicator.

III. RESULTS

Mean species abundance in the Czech Republic reached 31% of original biodiversity in intact ecosystems. That means that human pressures decreased original biodiversity on average by almost 70 %. The biggest impact was located in intensively used agricultural areas in the lowlands. Forested mountain ranges in the border areas, as well as other forested interior parts of the country, achieved the highest values indicating they present relatively best preserved ecosystems in comparison with other landscape ($MSA_{AVERAGE}$=23,7 %). However, the MSA in forested areas ($MSA_{AVERAGE}$=43,9 %) is still decreased by human pressure on average by more than half.

Although forested areas cover about 33 % of the Czech Republic, most of them are fragmented into small patches with an area less than 100 km^2 as a result of dense road network, urban areas and intensively used agriculture land.

While potential natural vegetation are represented on most of the area by mixed or broad-leaved forests with dominant proportion of oak and beech, due to economic pressure a lot of planted forests are monocultures, with coniferous trees occupying almost 82 % of forested area.

Only 1,2 % area of all forests in the Czech Republic can be regarded as natural forests close to its original condition defined by [6]. All other areas including protected forests are affected by long-term human influence resulting in significantly modified species composition, spatial and age structure and soil degradation.

IV. CONCLUSION

Forests present potential natural vegetation on most of the Czech Republic's area and thus provide important habitat for big part of original fauna and flora, as well as play important role for human society in provision of many ecosystem services. This study documents significant human pressure on forest ecosystems and their degradation.

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Use of Proba-V Images in Southern Africa for Dynamic of Desertification Indicators

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***Abstract*—In southern Africa, land degradation and desertification affect the territory to a considerable extent. Given the lack of economic resources to reverse the problem in many countries within the region, prevention mechanisms can be key to address further land degradation and desertification. The use of Earth Observation Data for analyzing land degradation and desertification dynamics, in southern Africa is widely and consistently used. Under the Desert watch Extension project a consistent methodology to attain an Indicator of Susceptibility to Desertification was developed. In this paper we aim to implement the Indicator for Susceptibility to Desertification through Desert Watch Extension methodology, but employing new Earth Observation Data from the satellite mission of the Project On Board Vegetation-Proba-V. Our preliminary results validated the use of this new Earth Observation data set for the analysis of the spatial variability as well as temporal dynamics of drought, one of the key driving factors of land degradation and desertification in the region.**

Keywords- the Southern Africa; desertification indicators; Proba-V; drought.

I. INTRODUCTION

This study aims to analyse the new dynamics of desertification and land degradation indicators in Southern Africa. The study area comprises Southern Mozambique, Southern Zimbabwe and the Northern part of South Africa. The research goal is to produce an Indicator for Susceptibility of Desertification (ISD) through remote sensing data, namely the Proba-V (Project On Board Autonomous Vegetation)[1]. The Proba-V is satellite mission from European Spatial Agency (ESA) and Centre National d' Etudes Spatiales (CNES) and is providing new Earth Observation Data since June 2013. This product has the same performance as the Satellite Pour l' Observation de la Terre – Vegetation (SPOT-VGT)[2]. Hence, it allows us to have series of data from 1998 to current days.

The semi-arid areas cover almost 16% of African continent´s surface and represent about 5.1 million km^2 [1]. Dryland degradation affects much of Africa, in general, and Southern Africa, in particular [2]. There are several studies that sought to discriminate between climate and human-induced dryland degradation in Southern Africa [3][4][5]. Among various factors, the cyclical occurrence of droughts at local level, as well as deforestation caused by farming and alike activities can increase the risk of desertification particularly in the semi-arid areas in Southern Africa [1]. The indicators about the susceptibility to desertification, particularly in the semi-arid areas in Southern Africa region, still requires further study. To what extent, through the use of the Proba-V-new remote sensing data - a steady and effective Indicator for Susceptibility of Desertification – ISD, can be obtained for Southern Africa? Our research goal is to employ the Proba-V satellite imagery and the DW-E methodology for obtaining an affective Indicator for Susceptibility to Desertification. We consider that using this new data could represent a crucial step for consolidating the understanding of the dynamics of desertification in Southern Africa.

II. METHODOLOGY

In Southern Africa region, the driest months are July and August, whereas the rainiest months are December and January. Fundamentally, in the study area, two main seasons can be identified. One is cold and dry and another is hot and wet with about the same duration length of 6 months each. However, a decrease in precipitation can increase the likelihood of severe droughts.

In the preliminary stages of this study, in order to calibrate the ISD using the new Proba-V images, the correlation between the Normalized Difference Vegetation Index (NDVI), extracted from Landsat (Thematic Mapper[3], Enhanced Thematic Mapper plus[4] and Operational Land

[1] Proba Vegetation: small satellite for global vegetation http://proba-v.vgt.vito.be/

[2] Spot-Vegetation programme http://www.spot-vegetation.com/

[3] Landsat Thematic Mapper (TM) https://lta.cr.usgs.gov/TM

[4] Landsat Enhanced Thematic Mapper plus (TM) https://lta.cr.usgs.gov/LETMP

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Imager–Thermal Infrared Sensor[5]), SPOT-VGT and Proba-V images, was investigated by each land cover class. The Landsat images were pre-processed: radiometric and atmospheric correction, dark-object subtraction method and cloud and shadow mask and upscaling for Proba-V and SPOT-VGT spatial resolution. The images used in the calibration were taken from the month of September (the end of the dry season) for the years 2001, 2008 and 2014.

The dynamic of desertification indicators include: a) the number of days per year with precipitation below 1 millimeter (RL1) was computed from climate reanalysis of the data from The European Centre for Medium-Range Weather Forecasts (ECMWF), and it was the input for climatic component; and b) biophysical component, which is based on NDVI and soil brightness analysis, by land cover class. As work in progress, the models of desertification indicators had been determined using geostatistical methodologies (kriging, co-kriging, stochastic simulations) with the biophysical and the climatic indicators [6][7][8][9][10][11][12]. This methodology coupled with field work (direct observation) will be pivotal to validate the findings as well as to ensure consistency.

III. RESULTS AND DISCUSSION

The Proba-V and SPOT-VGT data products had shown a significant correlation with Landsat image, allowing us to follow through with the next step, which is the ISD.

Despite the decreasing in spatial resolution from 30m (Landsat) to 100m (and 300m) (Proba-V), the temporal resolution was increased from 2 images per month to 6 (and 3) per month. This is one of the major enhancements that the Proba-V satellite provided on Open Earth Observation Data.

Our results about climatic component (see Figure 1 and Figure 2), suggest that there could be a steady relationship between the spatial dynamic of drought and spatial variability of semi-arid areas over the region. Figure 1 represents the Static Component, which is the average of the number of days per year with precipitation below 1 millimeter (RL1). The highest values of the average of RL1 (red spots), seem to be spatially distributed according to desert areas and semi-arid areas over the region. Figure 2 represents the Dynamic Component, which is the slope of the variance of number of days per year with precipitation below 1 millimeter (RL1). The areas with high values (in red) experience the major variability in rainfall and these areas are distributed according to the semi-arid areas over the region. Overall, the climatic component analysis seems to show high levels of consistency with previous work on spatial dynamics of land degradation and desertification in Southern Africa [2]. We are working on soil component and we expect to obtain desertification indicator results with different spatial resolution (100m, 300m) using Proba-V images.

[5] Landsat 8 OLI (operational Land Imager) and TIRS (Thermal Infrared Sensor) https://lta.cr.usgs.gov/L8

In conclusion, the ISD in semi-arid areas, where the range of drought periods differed in magnitude in space and time, is significant for resources management and sustainable development strategy at national level.

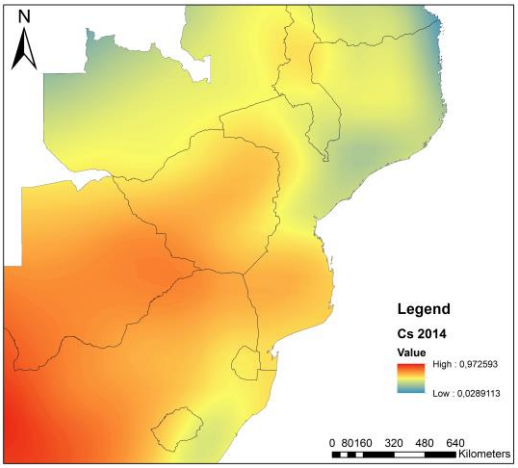

Figure 1. Climate Static Component

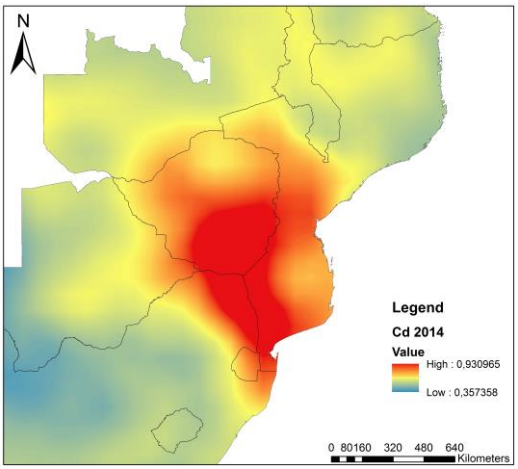

Figure 2. Climate Dynamic Component

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