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Future of Internet, Ecosystem Services and Sustainable Regional Development

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Future of Internet, Ecosystem Services and Sustainable Regional Development

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Abstract

The Internet is gradually turning into one of the most important critical infrastructures for the society and all economic sectors. Future Internet research and innovation take a solid part across all other Horizon 2020 domains and challenges, including Climate Action, Environment, Resource Efficiency and Ecosystem Services, trying to bridge the fundamental research and the need to conduct experimentally-driven research in real environments with the participation of all stakeholders. The Internet of Things (IoT) refers to a set of devices and systems that interconnect real world sensors and actuators to the Internet. According to Cisco, there will be over 50 billion Internet-connected devices by 2020[1]. This makes possible implementation of the Quintuple Helix model, which supports the formation of a win-win situation between ecology and innovations, creating synergies between science, economy and society [1]. The paper presents a use-case - Smart Forest Ecological Management System (ForEco), which embeds an expert system aiming at assessing conditions of forests and providing services and ground for informed management decisions to different end-users. ForEco will integrate a set of models to support the adaptive management of forest ecosystems in order to achieve their sustainable development and operation as a natural resource. ForEco is based on an analysis of a large quantity of open data from different international initiatives for satellite data exploitation and will support the decision-making processes of a variety of end-users. ForEco has got seed funding and support from the FIWARE Finodex accelerator[2].

Keywords: Big Data, Ecosystem Management System, Ecosystem Services, Forest Management, Future Internet, Internet of Things, Sustainable Development.

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Introduction

[1] http://www.cisco.com/c/en/us/solutions/internet-of-things/overview.html?
[2] http://www.finodex-project.eu/

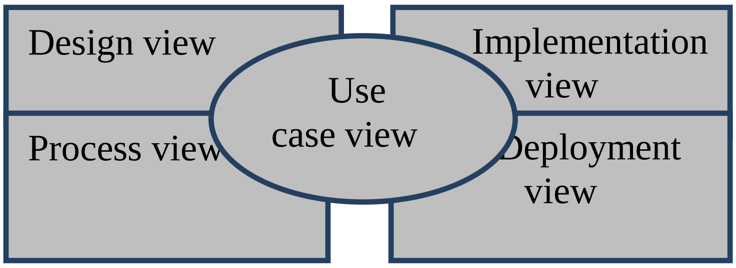
Two of most influencing paradigms in Information and communication technologies in the last decade are the Internet of things (IoT) and the Future Internet (FI). The underlining philosophy behind the IoT paradigm is to bind all existing material and ideal objects of the world to suppliers, and possibly consumers of information. FI could be considered as the next evolution of the Internet, which will allow peer to peer cooperation in large scale based on the following underlying principles – heterogeneity, scalability, robustness, modularization, loose coupling, locality, etc. [2]. FIWARE[3] is a middleware platform, driven by the European Union, for the development and global deployment of applications for FI [2]. It is a result of a public private partnership (PPP) for the creation of a large framework of open software components facilitating rapid development of FI and IoT related applications. FIWARE middleware consists of set of readymade components called generic enablers or for simplicity enablers. IoT approach is broadly used for creating of contemporary applications related with real time data acquisition, storage and processing of large amounts of data. The core applications of IoT [3, 4, 5] are in the areas of transport and logistics; smart places (homes, cities, and factories); retail; health; energy and energy grids. In the studied literature the authors did not find use-cases describing the application of IoT or FIWARE for Ecosystem Services Management. The main goal of presented paper is to outline some outcomes related to creation of a smart forest Ecosystem Services Management System (ESMS) named ForEco, based on the IoT paradigm. ForEco aims at providing an adaptive and environmentally sound management of forest areas, as well as a large set of materials that are closely related to the sustainable development of regions.

Materials and Methods

In order to achieve the goal stated, the following set of technologies, methods, and theories are applied. The use case for the system modeling and its references architecture creation is Unified Modeling Language (UML) as a common Meta language for information systems modeling. UML is a worldwide accepted for clear and unambiguous description of software applications. According to [5 and 6] the modeling of system architecture is centered on the use cases as it is presented on Figure 1.

[3] https://www.fiware.org/

Figure 1. *Use Case Centric Architecture*



The reference architecture of ESMS is developed by extensive usage of FIWARE middleware framework. The main advantages of such an approach are, among others, rapid development, reliability, heterogeneity, and compliance with similar external systems. Presented reference architecture is foreseen for ESMS implementation running in a Cloud and Fog computing[4] environment.

The implementation of ESMS ForEco is based on development of following three mathematical models: asset, supply and services assessment and valuation - Ecosystem Unit Valuation (EUV); Biophysical Forests Assessment (BFA-SPPAM) and a mathematical model of decision support systems - Value Based Model (VBM). The theoretical and methodological features of the models BFA-SPPAM [7] and VBN [8] have been published and EUV has been reported [9].

Results and Discussion

ForEco Smart System Architecture Description

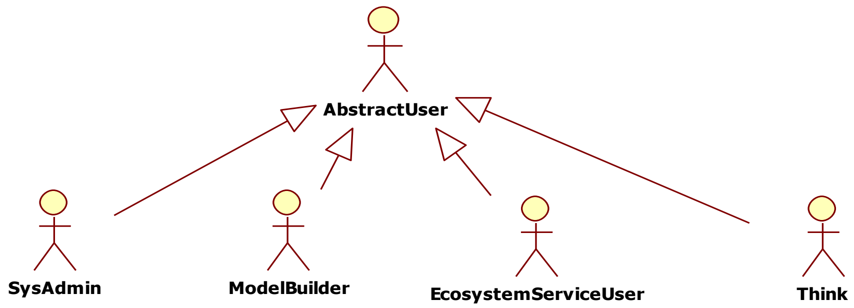
The application of use cases for the system modeling is presented in next two diagrams.

Main Actors and Use Cases

In order to describe the system architecture, it is necessary to describe the interacting main actors and the ways they do it (use cases) - Figure 2. All users presented have the same basic functionality. The introduction of the Abstract user is a common technique to outline same functionality for a set of users. The users also have additional specific functionality (use cases). The common use cases are: a) Sign in (The users enter their credentials and the system authenticates and authorizes them. Such users can be either humans or external applications. In case of external applications, the procedure follows the OAuth 2.0[5] requirements for identification); b) Sign out (users are no more allowed to interact with the system); c) Register (users enter requested identification information and additionally are approved by the System administrator).

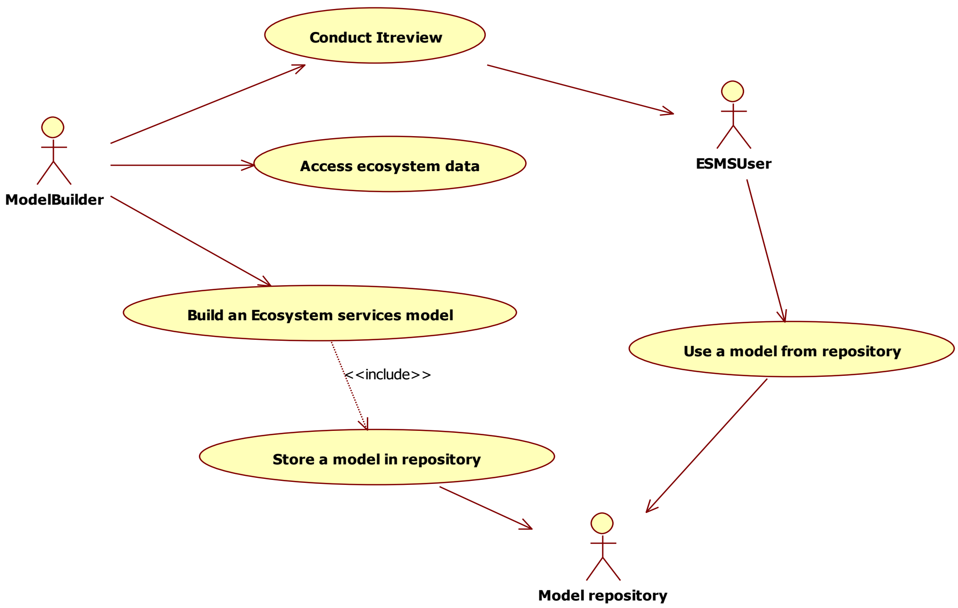
[4] http://www.cisco.com/c/en/us/solutions/internet-of-things/iot-fog-computing.html
[5] http://oauth.net/2/

Figure 2. *Main Actors of Ecological Management System*



The full description of all use cases defined for ESMS goes beyond the limits of present paper. In next lines, the very specific to ForEco case – creation Ecosystem services models, their storage, and usage are described. The interactions between three main actors – ModelBuilder, ESMSUser, and Model repository are shown on Figure 3.

Figure 3. *Use Cases Describing Creation and Usage of ESMS Related Models*



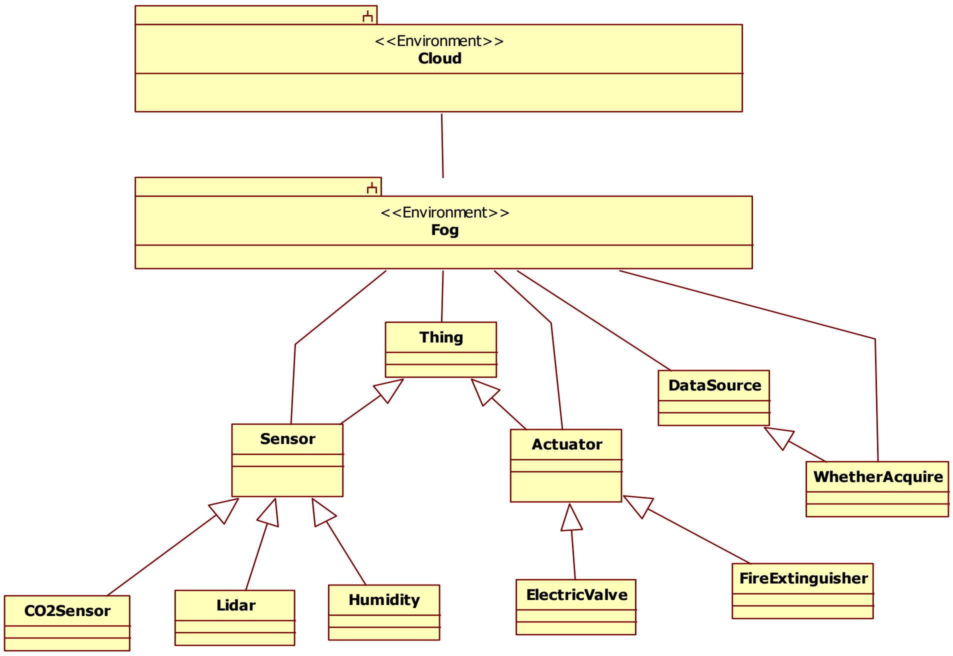
In the presented approach the VBM models are built after a set of interviews with Ecosystem services experts denoted as ESMSUser actor and VBM experts denoted as the ModelBuilder one. After the creation of a VBM model based on expert's knowledge, that model is stored into system repository for future use by ESMSUser actors. The model repository is denoted as Model repository actor. Usually the first two actors are humans and the third one is a database. In that use case diagram, the actor ESMSUser can be either expert, or Ecosystem services manager, or the both at the same time.

Having defined main actors and their cases, we may present a high-level architecture reference model of ESMS.

High Level IoT Related Architecture

The proposed high - level architecture is built according to the approach presented in [2, 3, 4, 5]. The server side of ESMS is running on two spitted environments – Cloud and Fog. The general view of ESMS architecture owing from interaction between things, Fog, and Cloud [10] is presented on Figure 4. All endpoint devices are considered as instantiations of classes of types Sensors and Actuator. We propose using of classes for presentation of things, because they have very close semantics. Classes and thing can be viewed as concepts having similar characteristics – capsulation, set of attributes and operations, and inheritance. The classes Actuator and Sensor are heirs of class Thing. The class Thing has basic functionality related with: data communication; authentication and security. These functionality can be built in a single inteligent hardware unit or in combination of physically separated hardware and software. The software can run on cheap computers as Rapbery PI and can support a multitude of devices. Additionally we consider also classes of type Source. They can be sources of information from open data origins. The purpose of Fog environment in presented high level architecture is to implement direct communication with Things and Sources. In Fog environment, the components like data brokers – mqtt, authentication - KeyRock, real time processing – Cepheus, initial data processing, data summarization, data control etc. can be placed. The destination of Cloud is to serve as environment for components related with Big Data, data analytics, modeling, model repository etc.

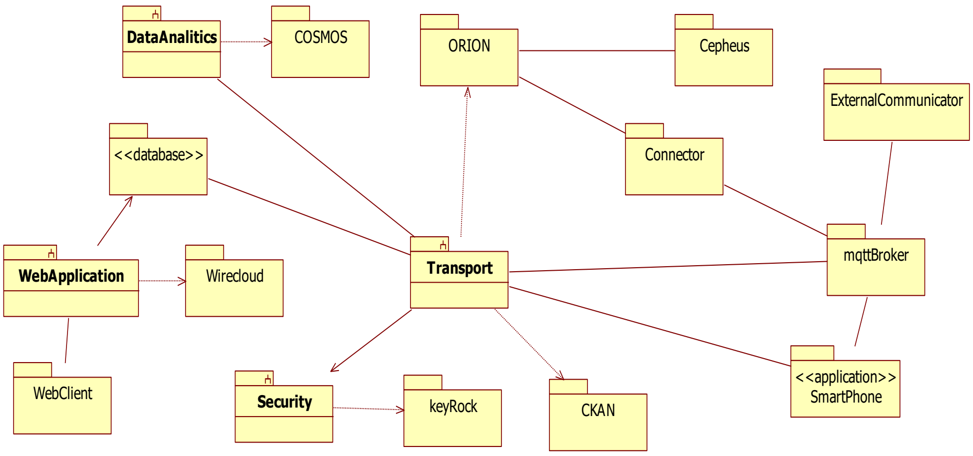
Figure 4. *Layered IoT Architecture for Ecosystem Services Support*



The package diagram of ESMS reference model architecture is presented on Figure 5. The description of the most important building packages (building blocks) is as follows: The role of the Transport subsystem is to coordinate all data flows between participating parties; The sources of information can be any IoT data supplier. Such a supplier can be a physical unit or open data source; The Orion Context Broker is a FIWARE enabler, which ensures data exchange between information producers and consumers – publishers and subscribers; The Cepheus enabler may be used when the data acquisition is in real time; CKAN is not a FIWARE enabler, but it is very important for data exchange with open data sources; A smart phone application can play a double role in the process as the both - publisher and subscriber; The package named ExternalCommunicator allows external data publishers and subscribers to interact with the system; The incoming data is propagated to all subscribed parties including the Data analytics subsystem and database; The Security subsystem is built using KeyRock identity manager; Data analytics subsystem is based on the extensive use of the Cosmos implementation of Big Data enabler for creation, use and deletion of private computing Hadoop clusters that will allow distributed processing of accumulated datasets; The end-user access to system is through Smartphone and Web application; The Web application is built on the base of the Wirecloud enabler.

The proposed architecture is implemented in an Open Stack environment - a free and open-source cloud computing software platform. It is designed to manage and automate pools of computer resources and can work with widely available virtualization technologies, as well as bare metal and high-performance computing (HPC) configurations.

Figure 5. *A Reference Architecture Diagram of EMS*



Models Description

The smart forest management system ForEco is developed as a Decision Support System (DSS) including originally developed models: Ecosystem Unit’s Valuation (EUV), Web based model for forest ecosystem state and climate impact assessment, or Biophysical Forest Valuation (BFA-SPPAM) and Value Based Model (VBM).

The EUV model is a set of formal definitions and functions related with the evaluated ecosystem unit (EU), as: the Ecosystem services function (E), the Natural capital value function ($\overline{C}$) and the Natural resources function (Φ).

E: $\Phi^{y} \times X \quad \rightarrow \quad \Phi^{y+1} \times \mathbf{I}$, **(1)**

where the state of natural resource for EU at y^th^ year is denoted with Φ^{y}, the expenses in ecosystem cervices are denoted with X $\subset$ R^+ and the income after their application as I $\subset$ R^+.

$\overline{C}:\Phi \rightarrow \mathbf{R}^{+}$, **(2)**

and $\Phi = \Xi \times \{V\} \times B \times \{W\} \times M \times \{\overline{W}\} \times \Pi \times \{\overline{\overline{W}}\} \times K \times \{\underline{W}\} \times S \times \{\overline{V}\} \times R \times \{\overline{\overline{V}}\}$ **(3)**

The elements of function (3) are the following separate sub functions: Total tree value function ($\overline{T}$), Herbal value function ($\overline{H}$), Mushroom value function ($\overline{M}$), Game value function ($\overline{G}$), Fruit value function ($\overline{F}$), Soil value function ($\overline{S}$) and Rock value function ($\overline{R}$). The Total tree value function evaluates tree stand in an EU:

$\overline{T} = T^{*} + C^{*} + F^{*}$ **(3.1)**

The formal definitions related with (3.1) for EU define the functionality of this sub function.

Definition 1: Tree species T = {t_i: i = 1,…, n_1}, where is t_i a tree species and n_1 is the total number of all possible tree species.

Definition 2: Tree reserve of an Ecosystem unit Ξ = { ξ_i : i = 1,…,n_1^*, ξ_i = {t_i,k_i,b_i}, $t_i \in$ T } where n_1^* is the tree species richness of a specific EU, k_i are their weights. b_i are the respective bonitos of that tree species. A graded scale presents the tree bonitos. The volume of all trees in the EU was denoted with *V* and with R^+ was denoted the set of all positive real numbers. *V* is measured in m^3.

Definition 3: Timber value function $T^{*}: \Xi \times \{V\} \rightarrow R^{+}$. The Timber value function evaluates the timber fraction in an EU.

Definition 4: Wood chips value function $C^{*}: \Xi \times \{V\} \rightarrow R^{+}$. The Wood chips value function evaluates the wood chips fraction in an EU.

Definition 5: Firewood value function $F^{*}: \Xi \times \{V\} \rightarrow R^{+}$, where R^+ is the set of positive real numbers. The Firewood value function evaluation evaluates the firewood fraction in an EU.

In all previous definitions, the variable t_i implicitly presents the price per cubic meter for that specific tree species.

Definition 6: Total tree value function $\overline{T} : \Xi \times \{V\} \rightarrow R^{+}$, where R^{+} is the set of positive real numbers. The listed other sub functions are developed in such ways. The application of developed EUV model for forest stands was reported [11].

The BFA-SPPAM is based on dendrochronological analyses and statistics by SP-PAM software [7]. For the BFA-SPPAM model a set of indicators for the forest state assessments were introduced: number of eustress periods; their duration, frequency and depth; eustress years (unfavorable climatic type of years), reactive tree functional type and eustress-climatic predictive patterns. The authors perceive eustress as a repeating state of diminished radial growth rate of tree stems within a period of one or multiple years and caused by unfavorable factors in the environment. This state encompasses numerous other reactions of the tree species. The level of radial stem growth (or tree ring width) is the main parameter that the developed application operates with, as well as the growth index, which is the main indicator for the statistical determination of low growth threshold (categorized as eustress) under the unfavorable climatic years. The growth index is calculated as a relation between the measured and the approximated values of ring width for each year:

It = MW/AW, **(4)**

where MW is the measured value of radial growth for a given year and AW is the value computed through an approximating polynomial equation. The calculation of growth index helps to eliminate the tree age as a main factor influencing the tree ring width. The confidence interval of indexes for each trustworthy tree ring sequence at the level of significance - α = 0.05 is computed. The study of the forest ecosystem assets state is based on an assessment of eustress depth (A) duration (D) - the number of adjacent eustress years, and frequency (F) - the number of stress years for a period of 100 years, and the creation of eustress nomenclature by 5-graded scale (Table 1).

$$A = \frac{1}{s}\sum_{i=1}^{s}(1 - It_i)$$

(5)

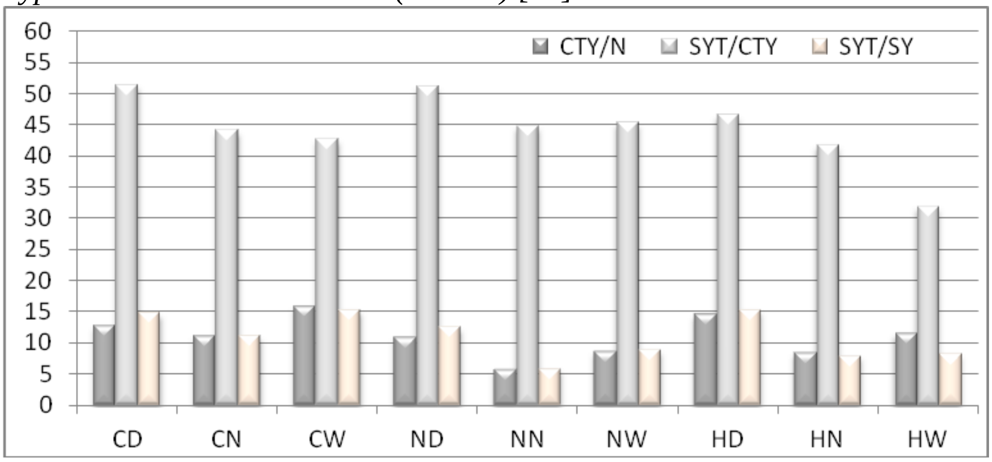
Table 1. *The Five-graded Scale for Assessment of Pinus Nigra Arnold. Eustress Features [12]*

Characteristics	**F**		**D**		**A**	
Group	name	value	name	value	name	value
1	Very rarely	≤39.55	Very short	≤2.176	Very small	≤0.2611
2	Rarely	>39.55-≤41.71	Short	>2.176-≤2.507	Small	>0.2611-≤0.2729
3	Normal	>41.71-≤46.01	Normal	>2.507-≤3.17	Normal	>0.2729-≤0.2965
4	Often	>46.01-≤48.16	Long	>3.17 -≤3.501	Deep	>0.2965-≤0.3083
5	Very Often	>48.16	Very Long	>3.501	Very Deep	>0.3083

Performance evaluation of eustress in particular localities allows the expression of reactive functional type of tree species, i.e. its behavior to climatic factors for decades. For example, functional type F4D5A4 means that in particular locality typical for trees of that species are frequent, very long and deep eustresses whose behavior puts the existence of the forest under some risk.

The next group of analyses conducted relate the eustress with climatic conditions. Therefore a climatic year (CY) is defined as the calendar year with the relevant average temperature and yearly sum of precipitations, and then a climatic type of year (CTY) is introduced as the climatic year with specific climatic conditions. These conditions are determined by deviations from proposed climatic norms of temperature (dT) and precipitation (dP). The climatic norms are considered as the mean values of temperatures and precipitations with their confidence intervals (µti, µpi) for every 30 years that the studied period was divided. The used climatic types are: HD - hot and dry (T>Tav+µti and P<Pav-µpi); CW – cold and wet (T<Tav-µti and P>Pav+µpi); HW – hot and wet (T >Tav+µti and P>Pav+µpi); CD – cold and dry (T<Tav-µti and P<Pav–µpi). Confidence intervals (µti, µpi) are calculated at a significance level $\alpha = 0.05$. Adverse climatic years are all climatic years that correspond to eustress year (SY).

Figure 6. *The Relative Importance of Climatic Types for the Presence of Black Pine Eustress (%): Climatic Types in Studied Period of Years (CTY/N); Stress Year Types in Climatic Types (SYT/CTY) and Stress Year Types in Stress Years Number (SYT/SY) [13]*



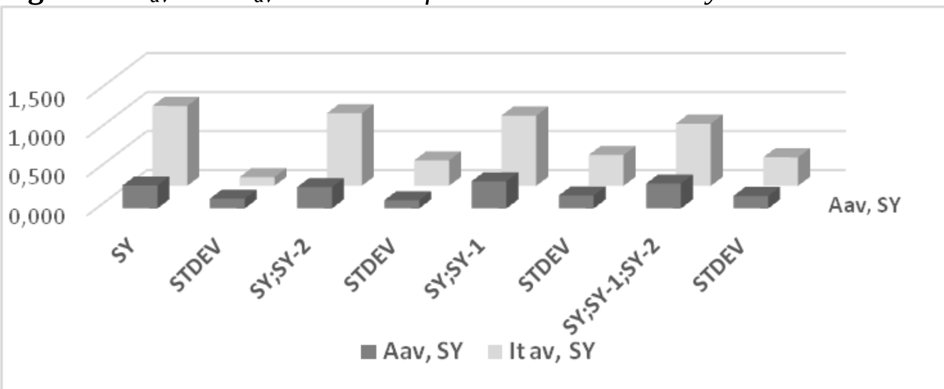
The main objective of the analysis is to manifest the importance of different CTY to the eustress occurrence (Figure 6). This analysis also examines the importance of climatic patterns for the presence of eustress - consistent CTYs for a period of two years before the eustress year. This approach allows predicting how the maintaining of certain adverse climatic regime or his sudden shift to another will affect the production of wood (Figure 7). Table 2 shows the CTY Changes by the Three Years Period for the Species Locations.

Table 2. *CTY Changes by Three Years Period for the Species Locations*

№	Scots Pine	Beech
1	D/W/ v.v.	W/D v.v
2	H/C v.v	C/H v.v
3	HD/CW/ v.v	CW/HD v.v
4	HW/CD v.v	HW/CD
5	**DDD***/DD/**D-D**/-DD	DDD/**DD**/D-D/-DD
6	**WWW**/WW/**W-W**/-WW	**WWW**/WW/**W-W**/-WW
7	CCC/CC/C-C/-CC	**CCC**/CC/**C-C**/-CC
8	HHH/**HH/H-H**/-HH	**HHH**/HH/**H-H**/-HH

* *With bolt noted the presence of eustress years in the corresponding climate type*

Figure 7. *It_{av} and A_{av} Variations for Beech Locations by Stress Patterns*



The application of the model to five coniferous and four deciduous trees has been published [14].

The VBM model presents a multiattribute utility function, developed on the Decision making theory, The Utility theory and a stochastic approximation technique used as machine learning [13]. The utility functions were calculated using the preferences of the Decision maker (DM), professional in forest ecology and environmental protection. The detailed methodology was published by the authors [15].

For the VBM model, we accepted tree indicators (sub-objectives or factors) adequately describing the main objective of the investigation. These indicators are: X_1 - timber reserves ($m^3.ha^{-1}$) as representing criteria for the assessment of economic effects or material services; X_2 - species richness ($n.ha^{-1}$) as the representing criteria for the assessment of ecological effect, or regulating and supporting services and X_3 - percentage of population employed in the forestry sector as representing criteria for the assessment of social effect or services. The model is developed as a multiattribute utility function with the three factors mentioned. The coefficients of function are computed using the preferences of ecology and an environmental professional. In the process of investigation independence by utility was found by the DM between the following factors: 1) X_2 from X_1; X_2 from X_3 and 2) X_3 from X_1; X_3 from X_2. The preferences of DM for x2 at different values of x1 and x3 do not change, suggesting independence of x2 from the changes of other two factors. Whatever the reserves of wood in the forest ecosystem and the employment of the population in the forestry sector may be different. In any cases, the preferences are directed to the presence of a large species richness of the forest, i.e. great variety of species of trees, grasses, moss, lichen, algae, and animal species that form the ecosystem and ensure its greater stability. The preferences of DM for x3 at different values of x1 and x2 do not change, suggesting independence of x3 from the changes of other two factors. This means that whatever the reserves of wood are and at different species richness of the forest ecosystem, in any case, the preferences are aimed at the increasing of number of workers in the forestry sector. At low timber reserves and a poor species composition, the increasing of employment in forest sector is motivated by the need of reforestation, regeneration, cultivation of existing forests, optimization of forest-related natural resources, development of alternative uses and others. At high timber reserves and rich species composition, the increasing of employment is motivated by the opportunities of multifaceted use of forests and the need of environmental management and balanced utilization of forest resources. Using the theory for decomposition of multiattribute utility to simpler functions given in Keeney [8] we determine the following multiattribute utility structure:

$$u(X) = k_1 u(X_1; X^o_2; X^o_3) + \mathrm{f}_2(\mathrm{X}_1) \times \left[u(X^o_1; X_2; X^o_3)\right] + \mathrm{f}_3(\mathrm{X}_1) \times \left[u(X^o_1; X^o_2; X_3)\right] +$$
$$+ \mathrm{f}_{23}(\mathrm{X}_1) \times \left[u(X^o_1; X_2; X^o_3)\right] \times \left[u(X^o_1; X^o_2; X_3)\right], \text{ were } u(X^o_1; X^o_2; X^o_3) = 0$$
$$\text{and } u(X^*_1; X^*_2; X^*_3) = 1.$$

(4)

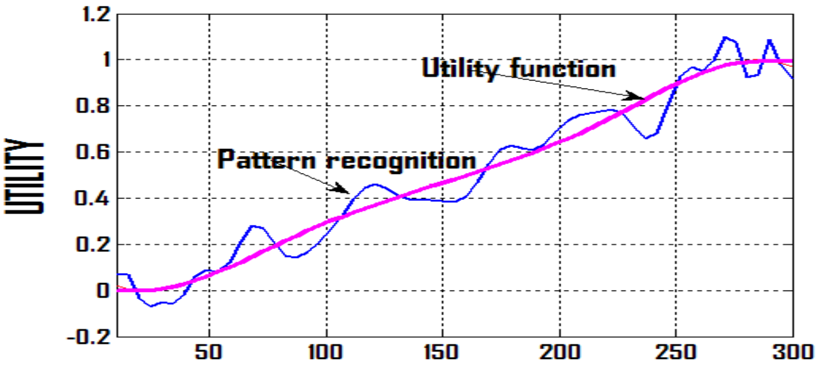
In the formula above $X^o = (X^o_1; X^o_2; X^o_3) = (10,1,1)$ and $X^* = (X^*_1; X^*_2; X^*_3) = (300,200,30)$. The functions f_2, f_3 and f_{23} have the forms:

$$\mathrm{f}_2(X_1) = u(X_1; X^*_2; X^o_3) - k_1 u(X_1; X^o_2; X^o_3),$$
$$\mathrm{f}3(X_1) = u(X_1; X^o_2; X^*_3) - k_1 u(X_1; X^o_2; X^o_3),$$
$$\mathrm{f}_{23}(\mathrm{X}_1) = u(X_1; X^*_2; X^*_3) - \mathrm{f}_2(X_1) - u(X_1; X^o_2; X^*_3).$$

(5)

Each of thise sixth functions is evaluated based on the DM's preferences. For example, the form of function $u(X_1; X^o_2; X^o_3)$ is given on Figure 8.

Figure 8. *Utility Function* $u(X_1; X^o_2; X^o_3)$



The wave line is the pattern recognition of the positive or of the negative DM's preferences. The solid line is the evaluated Utility function polynomial approximation $u(X_1; X^o_2; X^o_3)$. The comparison betwen the evaluated Utility function $u(10; X_2; X_3)$ and the evaluated utility function $u(300; X_2; X_3)$ is shown in Figure 5. The results of the model (C) application have been reported in a recent paper [16].

Conclusions

The proposed FI based architecture and a suit of models for biophysical assessment, valuation ecosystems and the management of ecosystems are applied for the first time. The proposed architecture and models are a ground for the creation of Ecosystem services management software applications. The originality of proposed approach consists of including three models as a base for the state and capacity of ecosystems assessment, their valuation and decision support for management of forest ecosystem services. The proposed EUV model for ecosystems units' valuation is more complete than similar studied valuation models [17]. The BFA-SPPAM model ensures a status assessment of forest ecosystems based on originally created eustress nomenclature. It also supplies an estimation of climate on forest ecosystems functioning. The base for the third method is the modeling of expert knowledge for helping ecosystems services managers in their activities.

The presented approach comprises all the phases of an information system design. During the first phase, the authors conducted a detailed research related to Ecosystem services management systems based on IoT and FIWARE and feasibility study. In the next phase, we defined the use cases and high-level system architecture is defined. After that, the mathematical models and FIWARE architecture reference were established. The conducted system design, the created mathematical models and the achievements reached in our previous investigation for forest biophysical assessments are ground for reaching Technology Readiness Level 3 of proposed ESMS. The next steps that have to be done are dedicated to Ecosystems services payments, which is in progress. We strongly believe that such a system will significantly improve the Ecosystem services management for sustainable regional development. In our future roadmap is included also research for establishing a common protocol for open ESMS models and data exchange. The ForEco system supports adaptive ecological management of forest areas to achieve their sustainable development and operation as a natural source of ecosystem services. Potential ForEco users are policy makers, governmental and municipal organizations (forest and landscape planners), experts from the Green Economy, Agricultural and Forestry sector, as well as the research and innovation organizations. The described models are under further development.

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