Complementary software solutions for efficient timber logging and trade management

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Abstract

Timber logging and trade is a complex system with important environmental, but also economic and societal dimensions. Today, the timber market has become global, not only for high-valued timber products, but also for technical and fire wood. At the same time, illegal logging is a common hurdle in almost all stages of the timber lifecycle from forest to market, creating a positive feedback cycle that starts with local environmental degradation and leads to severe impacts on global climate change. Timber certification and traceability are key aspects that may ensure supply-chain transparency, illegal logging mitigation, and forest management sustainability. Information systems have a central role to play in an application domain that is hardly digitized, such as forestry. Providing innovative technological solutions to support the daily work of the local forest service is critical, but the integration of ICT technologies in their operations is indeed a challenging endeavour. In this paper, a set of complementary software solutions is presented that aim to assist timber logging, transportation and trade management, and consequently to support efficient wood certification. The paper also outlines how forest service staff perceptions were integrated at an early stage in the design and development phase in order to increase system usability and maximise the potential for technology assimilation.

1. Introduction

Illegal logging and timber trade is currently a major concern among all countries worldwide [1]. It is largely acknowledge that, if related practices are left uncontrolled, they present a substantial threat to sustainable forest management with wider environmental and economical consequences. It is, directly and indirectly, associated to global climate change, threatening ecosystems and biodiversity in forests throughout the world. The degradation starts locally, with reduced forest cover affecting rainfall patterns, surface temperatures and atmospheric CO2 concentrations. Carbon emissions from deforestation, especially in developing nations, account for 15% of global carbon emissions, according to FCPF [2]. Several numerical experiments on deforestation in Amazonia have showed that temperature rises significantly and precipitation decreases as a result of deforestation. A positive feedback cycle with increasingly negative consequences starts to develop, with lower rainfall leading to reduced river flows to agricultural systems, lower water supply and increased pollution in air and water supplies. This pattern results in increased diseases in neighbouring rural and urban environments. Influenced by deforestation, changes in rainfall and temperature patterns topped by floods and landslides have regional effects that subsequently impact global circulation patterns in the atmosphere. In other words, the local effect, related directly to illegal logging activities, creates linkages, which disrupt global atmospheric patterns and contribute to global climate change in numerous ways.

While the negative impacts of illegal logging are gradually being acknowledged, the use of technological means to combat this phenomenon is not gaining ground as quickly as would be expected. One reason for this reluctance is linked to the fact that reliable information on forest

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harvesting activities is often difficult to obtain for legal and illegal activities, due to natural, geographical and administrative factors, among others. However, another critical reason lies with the rigidness of most IT systems designed for forest management, which either demand advanced digital skills, largely unavailable among forest service staff, or request that field experts change their daily operations significantly to meet the utilisation requirements of these systems. Such technological solutions, however efficient in producing the intended result, usually fail in gaining the necessary user acceptance and often become obsolete.

The AITOLOS[4] project is an initiative building on the close interaction of two types of partners: those experienced in the design and development of complex ICT solutions and those with forest management expertise and field-work experience. Both forest domain and technology experts have actively collaborated during a two-year period, in order to achieve mutual understanding on how each side could contribute to the overarching project goal, i.e. the design and implementation of technological solutions that complement traditional forest management activities in fighting against illegal logging and timber trade.

In the following sections, the design methodological approach is described and identified IT solutions are briefly presented. The sections highlight how user needs and traditional operations on the forest field were brought at central stage during system specifications' design and solutions development. The sections also discuss the aspects that ensured minimum intrusiveness of the selected technologies and the operational planning that facilitates the integration of developed IT systems in forest service operations.

2. A methodological approach for solutions' design and development

Identifying suitable technological solutions that support the efforts of the local forest service in combating illegal logging activities and selecting those that would be demonstrated through the AITOLOS pilot implementation in the Greece - F.Y.R.O.M cross-border area was a challenging process. Frequent interactions among technology and forest domain experts were implemented to pinpoint the key problems and needs to be addressed, to prioritise among them, and to estimate risks involved in developing a portfolio of IT solutions for the forest service on both sides of the border. The necessary bidirectional knowledge shift between the two types of teams was initiated with an intensive 'inception' workshop and followed by several meetings, field visits and workshops. The primary objective was to facilitate the development of a common language and to achieve consensus among technical and domain scientists on the needs and the suitability of proposed solutions. For this purpose, agile methods originating in soft-ware engineering were adopted, and put in action [3].

Capturing user requirements constitutes a moving target in projects that are ill-defined or rapidly-changing, which has shed a new light to the use of agile approaches like Extreme Programming or Scrum and their potential in capturing requirements informally, i.e. as users' stories. Agile methods for requirements engineering are based on four principles [4]: a) put customers in the centre of attention, i.e. involve actively stakeholders throughout the process; b) employ early verification and validation techniques, i.e by developing acceptance tests for user stories, or use cases; c) identify early non-functional requirements and analyze them with customers; d) manage change and incorporate it in the process of requirements engineering.

Cao and Ramesh, in [5], presented an empirical study that evaluates agile requirements practices in 16 organizations, and reveals that intensive communication between the developers and customers

[4]AITOLOS stands for "Cross-border collaboration to fight illegal logging and timber trade to protect trans-boundary Greek-F.Y.R.O.M. ecosystems". It is a project implemented under the IPA Cross-border programme and is co-funded by the European Commission. The project website is http://www.aitolos.eu

as the most important one. Inspired by agile requirements practices, a methodology for engaging end-users early in the process was developed and applied in the AITOLOS project.

The methodological approach employed in all teams' interactions was built on a 3-step structure i.e. the *domain understanding* step, the *solutions identification* step and the s*ynthesis and co-design* step. The process developed with this approach was not linear, but instead several iterations of these 3 basic steps were planned and performed.

The first step, *domain understanding*, was primarily built on eliciting initial user stories, which were subsequently developed through iterations. Domain experts described their application domain and presented problems in their everyday work practice in a story-telling fashion by sharing experiences and anecdotes. They also highlighted the real-life issues faced, the extent and detail of the illegal logging problem and the limitations in the way the forest service operates. The purpose was to achieve a common understanding between domain and technology experts about the scope of the project and the role intended for the complementary technical solutions.

The second step, *solutions identification*, aimed to provide basic knowledge to the domain experts on technology-related opportunities and to enable collaborative identification of possible solutions. Technology experts presented the capabilities of various relevant technologies and proposed possible systems and applications that could be exploited to meet some of the domain challenges. Through this step, domain experts gained insight on technical capacities and limitations and the possibilities linked to the integrating innovative solutions to improve the efficiency, support, or simplify their every-day work.

The third step, *Synthesis and co-design*, was the richest one in the number of teams' interactions. Its purpose was to produce a synthesis of views between the domain and technical experts and to prepare the ground for the compilation of technical system specifications and a tailored operational plan for the adoption and utilisation of the developed solutions on each side of the border. User stories from the first step were exploited to produce high-level needs' requirements of the project at hand. The final selection of technologies to implement was preceded by a step of prioritisation in terms of IT system electiveness, implementation risk and management/ maintenance cost.

3. Analysing the operational framework

The timber logging and trading lifecycle can be analysed in five key phases that typically involve several authorities, regulations, operational frameworks and markets [2]. *Forest management and timber marking* is the first phase and relates to medium/long term forest management plans and possibly market needs. This phase is followed by the actual tree logging activity in the *wood felling and pilling* phase. The third phase, t*imber delivery & transport* phase is related to timber pick up and transportation from pilling areas to facilities away from the logging area. This activity is followed by the *timber storage* phase, during which timber is taken to storage or processing facilities. From this point on, wood becomes a product that is traded and processes in local or global markets and thus the fifth phase of its lifecycle is related to cross-border timber trade towards global markets. As the timber lifecycle spans across several sectors, scales and domains, typically there is limited information collected for each phase, while interoperability and common information systems are highly uncommon.

In the framework of the AITOLOS project, an ambitious goal was preset in terms of fostering cross-border collaboration and coordination between the activities of *Greece* and the *former Yugoslav Republic of Macedonia* against illegal logging and timber trade. Thus, an analysis of the overall logging and timber trade lifecycle was performed with participatory methods and agile techniques. Through this process, the domain and technology experts managed to spot the *weak links* of the added-value chain, which could potentially be improved by software solutions and tailored IT systems. The participatory process included first an initial assessment of lifecycle weak points that required attention, based on bilateral discussions with involved stakeholders and based on respective industry expertise. Subsequently, a broad stakeholders' survey was set-up to assess the identified weak points and enhance the analysis with the feedback from forest management policy experts, forest service staff members, wood traders, wood-logging partnerships, environmental NGOs, etc. The outcomes of this participatory process were not only synthesised and processed towards the development of technical solutions, but were also exploited for the development of relevant policy guidelines that aim to support the fight against illegal logging and trade.

The analysis of the operational framework yielded added value conclusions that affected the subsequent selection of technological solutions. The following representative examples can be mentioned: It was drawn that systematic operationalisation of control/check-points across key wood roads to monitor movement in and out in areas close to log landing areas was needed. These permanently set-up check-points should constantly control the vehicles entering and exiting the log landing areas in order to reduce illegal activities and relief/replace staff surveillance rounds. It was also concluded that the use of uniform templates to report import and export of wood across Greece-FYROM borders (e.g. language, volumes, destination etc.) are needed and smart identification technologies would assist control services in their work. The objective is to eliminate non-uniform documentation that escorts wood loads across the border and thus the use of a common language will ease the legality control at the border and check-points.

4. Technologies built to provide solutions to existing problems

The results of the operational framework analysis, along with the conclusions drawn from the application of agile and participatory methods were processed by domain and technology experts, who focused on the identified weak points of the timber logging and trading lifecycle and collaboratively selected technical solutions that would provide solutions to specific problems. The criteria for this selection primarily respected the existing mode of operation of the forest service and targeted the design of tailored IT systems that would require minimum digital literacy and would reduce the intrusiveness of technologies as seen from the users' perspective.

The design and development of the AITOLOS technical solutions, and their demonstration through a pilot activity in both countries, was based on the principles drawn from the aforementioned process: 1) wireless access technologies (smart identification, e.g. RFIDs) can increase accuracy and reach of the marking process, 2) image processing techniques can be exploited to calculate the loaded wood volume on the vehicles that transport them from the log landing areas to the warehouses, improving the accuracy of current empirical calculations, 3) wireless communication and server systems could be utilised to store and communicate required data among relevant stakeholders across the value chain (e.g. custom control to forestry offices) to manage timely information transfer and control of matters related to the legality and routes of transportation, 4) GIS/geo-systems platforms and software would enhance accuracy and efficiency of managing forest areas, whether real-time or off-line, would support the forest area monitoring activity and help authorities locate areas where illegal logging is taking place, in order to focus their efforts in controlling it, 5) electronic IDs in consignment notes would eliminate reporting fraud.

Below, we provide a list of complementary IT solutions that were proposed towards an improved *modus operandi*, enhancing process transparency and allowing for the timber-origin certification.

S1: Electronic documents with security characteristics. There are several documents involved in timber as logging permits and timber transportation notes (which accompany trucks from log landing areas to timber warehouses). Modern document templates may incorporate security features in the form of barcode, QR code, or e-signatures, which are instantly verifiable. Using low cost, smart devices, such features can be verified instantly.

S2: Smart Tags for Timber Marking: Currently, timber marking is performed with hammers that mark wood with forest office, or forester code. This is a weak point that can be significantly improved by introducing unique tags for all wood marked by hammer. This can be achieved by using plastic bar- code or RFID tags, or RFID nails from pulping compatible material. This solution is ideal both for proving technical wood log origin, and for timber certification.

S3: Cross-border uniform, multilingual reports. Forms attached to timber imported (or exported) are not standardized, and texts appear typically in the national language. A form standardization process that involves multilingual forms and common coding for species can remove language barriers at inspection points.

S4: Truck load detection. Manual estimation of timber volume loaded on trucks is another weak point of the value chain. Using a one-stop gate, equipped with low cost, low power sensors to calculate automatically wood volume loaded on a truck. This could be done for example by two depth cameras getting two viewpoints of a truck: top and rear, and detecting the contour of the volume loaded. We are currently in the process of deploying this solution, which will be presented at the conference.

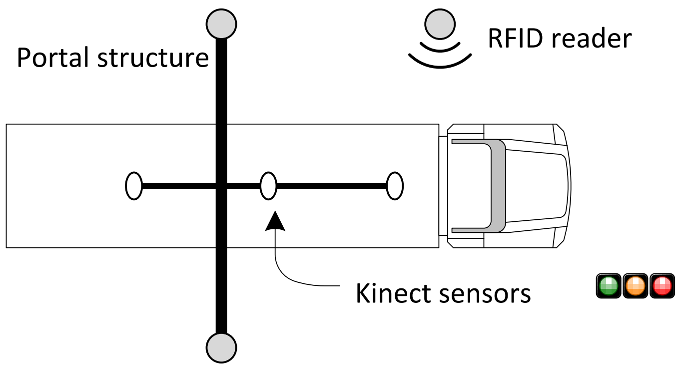

Figure 1. Load volume measurement

S5: Truck motion detection. While effective monitoring of timber transport and access control to forest areas has been identified as a key to combat illegal logging, this is a very difficult task, as forests are not fenced and a dense network of dirt roads and paths exist. However, a typical fleet management scenario that uses GPS/GSM network to detect truck routes, and report them online could be easily deployed.

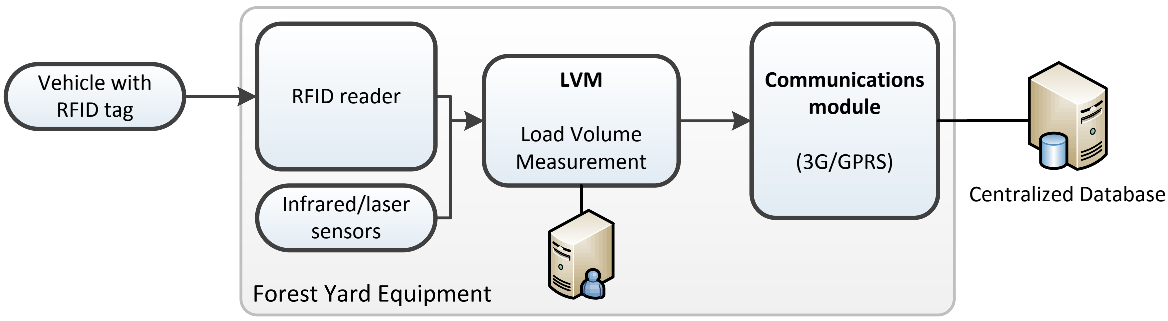

Figure 2. System architecture for vehicle tracking on forest yard gate

S6: Satellite imaging. Image processing algorithms may be applied on satellite images to detect areas of intervention and protection. Such tools have been applied extensively in forest fire monitoring. With respect to timber logging and trade, we identify two scenarios: The operational scenario, where images are used on demand, in order to identify illegal logging at the time it happens, and the strategic scenario, where the same techniques may apply on low-cost, historical images, to estimate forest degradation due to illegal logging and prioritize future intervention actions.

S7: Systems integration. In the current situation, information doesn't flow across the borders, neither between the various national services involved in the inspection of timber trade value chain (i.e customs, taxation, police and forest authorities). An integrated Environmental Information System could be deployed to link customs with taxation offices and forest services, in order to share information related to authorised timber transport, timber storage in warehouses, etc.

5. Discussion

Environmental Information Systems may become extremely valuable for efficient timber logging and trade, and support for both timber provenance certification, and forest forensics. Timber certification and traceability are the main two elements to ensure supply-chain transparency, illegal logging mitigation, and forest management sustainability. Environmental Management Information systems may become a key element for such an endeavour, and in the framework of the AITOLOS project we previewed a set of complementary solutions that spans across the lifecycle of timber value chain and currently we are in the process of deploying a subset.

The AITOLOS project pilot designed and currently deploy a prototype for detecting trucks load using low-cost depth cameras and RFID technologies. The two pilot sites have been selected, the first is in Goumenissa, Greece and the second in Bitola, The former Yugoslav Republic of Macedonia. The pilot implementation is expected to yield important results and insights on how Environmental Management Information Systems together with low cost sensors can assist in fighting illegal logging and timber certification, and how illegal logging is performed in the local cross border environments.

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