Technology Risk Management in Agriculture Engineering

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Abstract—The objective of the paper is to propose a risk assessment model for agricultural engineering related to bio-safety and security while deploying agriculture information through the latest computing and communication technologies for farmers. The earlier works concentrate much on the biological risk and agricultural risk without focusing on the effects of uncertainty in different computing and communication technologies on agriculture. The agricultural risk is considered as a net effect of uncertainties in processes performed during a particular phase or season by a subject on the objects through particular method. A mathematical model for assessing the overall agricultural risk arising from the various uncertainties in processes of extending the latest technologies to agriculture business is proposed. The main focus of the paper is to analyze and mitigate agricultural risks towards healthy crops, nutrient soils for adequate food production in the market with a better environment to the society.

Index Terms—BioSafety, BioSecurity, Risk Assessment, Business process, Uncertainties

I. INTRODUCTION

An important area of application for information and communicational technology is improving the quality and quantity of the agricultural products and using the land soil nutrients, water, pesticides more efficiently and effectively. The agricultural engineering includes power and machinery, control systems, soil and water conservation, pest solutions, environmental hazards, food and aquaculture. The modern communication and computing technologies are to be integrated with agricultural engineering to improve the quality of agro products and profits through a number of concurrent agro processes. The internet, social networking or other global networks enable the farmers to plan, decide, and act on the agriculture processes which leads to a profitable business process. For instance, timely request for best seeds and need of pesticides and precautionary service of machineries are meaningful to avoid time consuming activities during pre-harvesting and post harvesting or other critical working conditions for better irrigation and water treatment, the Integration of computer techniques towards water management is required. However, it is the responsibility of the agro service provider to carry the benefits of the technologies to the agricultural society.

In the context of process network the agriculture may be considered as a collaborative process improvement network where research and various agricultural administration, agricultural consultants, agricultural professionals, contractors and cooperatives are sharing their information [1]. The risks associated with the computing and communication technology towards agricultural science and engineering are due to uncertainties in the weather prediction, unlimited variety of crops, need for biosafety and fertility of the soil. For example, in the computation process context implementation of new sensors and its applications towards the agricultural product identification will be a communication risk in the product oriented traceability. Safety risk is associated with the development of detection systems and models that track microbes and toxic contamination. The sustainability is the assessment of environmental impacts of individual products whereas bio security demands the waste treatment and facing the risk of adulteration of incompatible ingredients to the food products [2]. Biotechnology and genetic engineering where engineers use living organisms and parts of organisms to produce new products and modify and improve existing ones are risky to environment. The habitat changes have disproportionately affected the vulnerable desert, semi-desert, and mountain ecosystems and have had an attendant and compounding effect on climate [4].

The primary concerns in agriculture with regards to Genetically Modified Organisms (GMO) are centered on environmental risks and safety risks to humans. Genetically Modified (GM) technology increases agriculture yield and in the other hand it is harmful to the soil by destroying natural supportive germs and worms. Climate variability causes considerable economic risk to the agriculture, forest, and water resources.[5] Most of the agricultural applications are developed by a non deterministic weather prediction which is a major threat during pre-harvesting and harvesting seasons. The data collection, generation of forecasts, developing and using simulation models to link climate, agriculture, and water resource systems, as well as understanding the economic and policy environments that affect how farmers and other climate information users apply that information [6]. If there is no willingness from the administration to share the
critical agriculture information to the farmers that leads to product risk due to policy of administrators or governments. Apart from the inadequate communication infrastructure in the villages and unequal ownership of computing resources; the literacy level of the farmers, non-co-operation of government authorities and discrepancy in the deployed agriculture information are some of the causes of agriculture risks. At times, risks may arise from the quantum of change involved the use of certain technologies that have not had extended field use, complexity entailed in the application of software; and resistance to the application of information and communication technology from certain vested interests [7]. In the communication technology prospective the farmers can be linked by a heterogeneous network that carry a huge amount of agriculture information in a low bandwidth. At the same time millions of actors in the agricultural process share the information making a network congestion and network failure. The security and reliability are also the important cause for the technology risk in agriculture engineering [8].

The paper is organized as follows; Section II illustrates the various risk layers focusing the process risks and Section III describes the mathematical model of agriculture risk assessment proposing a definition of agriculture risk and calculation in terms of bio risk. In section IV discusses risk mitigation techniques and management solutions focusing the bio attributes like safety security and sustainability. Section V brings out simulated results of the model in terms of communication and computing risk for different agriculture phases.

II. RISK LAYERS IN AGRICULTURE ENGINEERING

The technology risk management system may be composed of many different sources of risk that affect the soil, water, crop and people. The risk may be viewed as a set of layers due to technical appliances and applications in computational and communication processes as shown in figure 1. The innermost layer represents the risks due to the uncertainties in the processes of computing related to agriculture engineering. For example, the distributed seed supply management techniques, weather prediction methods and the analytical methods used in the small and medium sized soil which are of different types. They have the high degree of unreliable and uncertain risk due to wrong soil analysis and improper seed selection that may affect the yield and market. The accurate determination of a seed for a particular crop in a specific soil is varying with respect to various agricultural phases or seasons. The product marked analysis and the demanded quantity of agricultural products of specific area are also complicated computing processes. These uncertainties lead to computational risk in the agricultural engineering. Even though the agricultural portal service may provide better interaction between the farmers and the agricultural technology center, due to the uncertainties out of the computational complexity in the quantity of fertilizers and pesticides determination may seek a risk. The various risk attributes in all the phases of agriculture are shown in Table I.

<table>
<thead>
<tr>
<th>Season</th>
<th>Subject</th>
<th>Method</th>
<th>Object</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preharvest</td>
<td>Seed and Soil Analysis</td>
<td>Not determined</td>
<td>Water Level</td>
</tr>
<tr>
<td>Sowing</td>
<td>Mobile</td>
<td>Not informed</td>
<td>Manure</td>
</tr>
<tr>
<td>Germination</td>
<td>Weather prediction</td>
<td>Rainfall</td>
<td></td>
</tr>
<tr>
<td>Florent</td>
<td>RFID</td>
<td>Physical appearance sensing</td>
<td>Flowers</td>
</tr>
<tr>
<td>Stem Growth</td>
<td>Media</td>
<td>Broadcast protection methods</td>
<td>Plant</td>
</tr>
<tr>
<td>Grain Growth</td>
<td>Pesticides</td>
<td>Diagonse</td>
<td>Diseases</td>
</tr>
<tr>
<td>Post Harvest</td>
<td>Portal Services</td>
<td>Cyber Crime</td>
<td>DOS effect</td>
</tr>
<tr>
<td>Storage</td>
<td>Marketing technology</td>
<td>Calculate</td>
<td>Seed prices</td>
</tr>
</tbody>
</table>

The second inner layer represents the risk due to the communication process over heterogeneous networks and media. The risk are due to the single point of control and execution in the case of sensor network if deployed in the field. Due to the uncertainty in the mobility of the animals the sensor network may face erratic information, which is a risk to the animal and the farming process. A separate communicational network with maximum availability and security is needed to bring the benefits of the technology to the cultivating farmers. Television and radio technology...
may not reach all the remote rural areas and in addition the literacy level of the farmers is not so considerable. The technology for the automated monitoring of fields during the irrigation phase the water management may lead to a product risk due to inaccurate and unreliable modern sensor networks. The satellite and mobile communication technology have an excellent impact on agricultural engineering but due to the low availability and security in the public networks, the agricultural engineering faces a security and privacy risk over the agricultural information. The two inner layers of the risk due to the exposed uncertainties are responsible for the third layer that represents the bio risk. The bio risks can be grouped into soil risk, plant risk, water risk and animal risk. These bio risks are the inputs for the overall agriculture risk in each and every agricultural phases. The agricultural risk can be categorized into production risks, market risks, environment risks and global risks. The agricultural risk may be considered as the cumulative propagated effects of all the technology risks in all phases of agriculture starting from ploughing and sowing to harvesting and post harvesting is shown in Fig 2

III. MATHEMATICAL MODEL OF AGRICULTURAL RISK ASSESSMENT

The agricultural risk is considered as an cumulative effect of uncertain and unfavorable economic consequences due to uncertainty of a process performed by a subject $s$ thorough a method $m$ on an object $o$ over a phase or season $p$ involved in that agricultural process. To illustrate, an irrigation process may be considered in which farmer as a subject $s$, watering is a method $m$ and crop is an object $o$ in pre-harvesting season $p$. Risk is a tuple consisting of variables pertaining to season, subject, method and object.

\begin{equation}
\text{Risk} = (p, s, m, o)
\end{equation}

In some cases there would be correct method but in a wrong phase, or incorrect method in a correct phase. For example a farmer may know the precise method to sow seeds but if the sowing done in a wrong season then it may result in low yield or a farmer may not know the sowing method, then though the sowing is carried out in the correct season it would still result in a low yield. Risk may result due to application of a correct method over an incorrect object, or an incorrect method over a correct object. For example if watering is done on date palms which actually doesn’t require watering will result in crop failure, and if excess of watering is done in a correct seed will also result in a crop failure. The agro risk is the total effect of the risks to people, plant, soil and water altogether known as bio risk where, this bio risk is inturn the effect of computational and communicational risks. Uncertainties are due to lack of knowledge about the structure of various physical and biochemical processes and also to the limited amount of data available. In the context of agriculture engineering, risks are classified as tangible and intangible objects ranging from land, people to lack of information and communicatoin networks. The paper focuses on intangible objects involved in computing and communication technologies. Now bio-risk may be considered as an effect of uncertainty in the processes due to inter related computational and communicational risks over the agricultural phases from pre-harvesting to post-harvesting.

This can be equated to:

\begin{equation}
R_{BIO} = \sum_{i=1}^{s} (R(CP)_i \ast R(CM)_z)
\end{equation}

where,

$i$ = phase/ season

$s$ = total number of seasons/ agriculture phases

$R_{CP} = CumulativeComputationRisk$

$R_{CM} = CumulativeCommunicationRisk$

\begin{equation}
R_{CP} = \sum_{j=1}^{m} [R(s_j) + R(m_j) + R(o_j)]
\end{equation}

where,

$m$ = total number of computation processes

$j$ = possible computation risk.

\begin{equation}
R_{CM} = \sum_{k=1}^{z} [R(s_k) + R(m_k) + R(o_k)]
\end{equation}

where

$z$ = total number of possible communication risks.
The agricultural risk is a consequence of all the biological risks and it may be defined as a cumulative of bio risk represented as,

\[ R_{AGRI} = \sum_{c=1}^{s} R_{BIO} \] (4)

\[ R_{AGRI} = \sum_{c=1}^{r} (R_{CP} \ast R_{CM}) \] (5)

\[ R_{AGRI} = \sum_{c=1}^{s} \left( \sum_{j=1}^{m} \left[ R(s_j) + R(m_j) + R(o_j) \right] \ast \sum_{k=1}^{z} R(s_k) + R(m_k) + R(o_k) \right) \] (6)

### Table II

**Agriculture Risk Attributes**

<table>
<thead>
<tr>
<th>Agricultural Season/Phases</th>
<th>Weight age</th>
<th>Computational Risk</th>
<th>Communication Risk</th>
<th>Bio risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre harvest</td>
<td>0.1</td>
<td>0.5</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Sowing</td>
<td>0</td>
<td>0.9</td>
<td>0.9</td>
<td>0.8</td>
</tr>
<tr>
<td>Germination</td>
<td>0.8</td>
<td>0.5</td>
<td>0.7</td>
<td>0.4</td>
</tr>
<tr>
<td>Harvesting</td>
<td>0.4</td>
<td>0.9</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Post harvesting</td>
<td>0.2</td>
<td>0.2</td>
<td>0.8</td>
<td>0.3</td>
</tr>
<tr>
<td>Agriculture risk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

With respect to the weight age associated to the agricultural phase, the various computational and communication risk are simulated according to equation 5 and shown in figure X.

The multiplication operator in the above equation represents the significance of interrelated communicational and computational risk. For example if communication risk is considered there are farmers in remote villages where there is no communication network for them. Even if there is an extended network the agricultural application software may not have a multi-lingual support so as to be understood by...
the illiterate farmers. The model is simulated for different probabilities of risks that may be caused in different agricultural phases are shown in Fig 3, 4, 5 and 6.

IV. RISK MITIGATION AND MANAGEMENT

The sources of risks are identified from various phases of the agriculture and classified according to their nature whether they are safety or security or integrity risks. Then they may be further classified into technical and non technical risks. The various possible causes for these risks can be identified and then prioritizing the risks based upon the severity, frequency and variability. For example, the very unreliable power and portable water supplies are major causes of post-harvest losses and a serious constraint to the development of milk pasteurization units and meat storage facilities. This is one kind of technical risk with a periodic occurrence in the agricultural process. The non technical risks is due to limited essential marketing linkages (local and overseas) and restricted knowledge on the existing trends in prices and demand and supply situations. Information (on existing acreages, cost of production, seasonality, etc.) required for farmers’ planning purposes is poorly collated. Due to inadequate nutritional programs milk productions and reproductive performance of all livestock classes may go down, that may be classified as agriculture supportive risk. These types of technical, nontechnical and supportive risks may be mitigated and managed by declaring number of policies from the government to the private research organizations to promote the agro processes. The risk management activities should concentrate the bio attributes of the agriculture engineering. The producers have to be given speedy access to information of production and marketing through communication technology. The rural people may be given awareness and training not only in the latest equipment handling but also the use of latest technologies of production and marketing opportunities through communication technology. From the information technology context, starting of agro-processing centers in each village for primary processing of food grains, fruits and vegetables and developing market network for purchase or supply of processed material from agro-processing centers are needed. There is a need in developing proper network and infrastructures for popularization of agricultural machinery for crop production, and setting up agro-processing center. The bio attributes like bio-safety, security, integrity and sustainability are to be given importance in promoting the soil quality, pesticides quantity and nature of fertilizers. Bio safety refers to a set of measures aimed at regulating and ensuring the safe use of genetic engineering and transnational movements of genetically modified organisms and reducing the risk of food bacterial contamination. Agricultural scientists study farm crops and animals and develop ways of improving their quantity and quality. In recent years, a number of ways were identified to improve crop yield, control pests and weeds more safely and effectively, and conserve soil and water. At the same time, the bio-security that prevent the use of dangerous pathogens and toxins for malicious use, as well as by customs agents and agricultural and natural resource managers to prevent the spread of these biological agents in natural and managed ecosystems. The bio integrity is built on the assumption that a decline in the values of an ecosystem that are primarily caused by human activity or alterations. The relation between bio security and bio safety is that no bio security with out bio safety. The more an environment and its original processes are altered, the less biological integrity it holds for the community as a whole in agriculture engineering. The bio safety protects people from germs whereas the bio security should protect germs from people. The bio attributes and the possibility and likelihood of agriculture risks are shown in Table II

TABLE III
BIO ATTRIBUTES AND AGRICULTURE RISKS

<table>
<thead>
<tr>
<th>Bio attributes</th>
<th>Possibility</th>
<th>Chance</th>
<th>Probability</th>
<th>Likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biosafety</td>
<td>Monotonous cropping</td>
<td>Infertility</td>
<td>Low yield</td>
<td>Plant risk</td>
</tr>
<tr>
<td>BioSecurity</td>
<td>Genetically Modified crops</td>
<td>Loss of Flora &amp; Fauna</td>
<td>Biodiversity</td>
<td>Harmful effect on Humans</td>
</tr>
<tr>
<td>BioIntegrity</td>
<td>Chemical fertilizers, Pesticides, Herbicides, Fungicides</td>
<td>Soil acidification</td>
<td>Toxicity</td>
<td>Soil risk</td>
</tr>
<tr>
<td>BioSustainability</td>
<td>Poor cultivation methods</td>
<td>Soil degradation</td>
<td>Loss of native crops</td>
<td>Environmental risk</td>
</tr>
</tbody>
</table>

The top four components in a layered order of safety and security qualities are shown environmental systems, agri-food production, water management, food processing and crop processing. Sensing of soil fertility to vary fertilizer application rates is an example of a potential development of smart machine systems for use in precision agriculture. The green revolution will continue with a resulting emphasis on preservation and sustainability of natural resources, food quality and safety, worker health and safety, animal care and welfare, and a reduction of environmental hazards [3]. In future: Biodegradable sensors for temperature, moisture history of stored food. Nanotechnology holds the promise to exceed the advances achieved in recent decades in information and computer technology and biotechnology developing a nano-scaled surveillance system for the safety and security of todays agricultural products with capabilities of identity preservation and tracking.
V. CONCLUSION

The information and communication technology help to reduce the negative effects of low yield due to pests and diseases and mitigate the risks of floods, draughts and long term climatic changes. But these technologies also have some adverse effects on agricultural engineering due to the lack of massive computation and communication resources needed. The risk due to the latest technologies is discussed in a layer form and a mathematical model for analyzing the risks is proposed. The effect of the individual technology risk on the agriculture is explored as risk propagation and simulated over different agricultural phases. The bio attributes are studied to mitigate the various types of technology-oriented risk on the forming and agricultural business. It is found that the inevitable agricultural risk can be managed by improving the infrastructural facilities in terms of computation and communication and extended to the rural farmers. The basic traditional farming methods and the latest nano technology are to be carefully exercised to the uneducated farmers of different regions not only to preserve the soil but also the global environment. The work may be further extended to the supportive agricultural oriented activities like animal husbandry and diary development. The risk associated with the low waged agricultural labors, contract labors and agricultural societies are to be studied in the future work.

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