Towards an Agriculture Information Ecosystem

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Abstract

Stakeholders of a domain in their day today activities generate information which is a valuable resource. To obtain full value of this information it should reach right people at the right time. To investigate how this can be achieved we developed an information flow model for agriculture domain by mapping information needed by stakeholders to information generated by others using set of aggregation and disaggregation operators. We found majority of information needs of stakeholders can be fulfilled by applying these operators to information produced by some other stakeholders thus creating a direct benefit to encourage sharing information. This information flow model had many similarities to biological ecosystems where nutrient cycles and energy flows are replaced by information flows. Based on this information ecosystem model we are developing a mobile based information system for farmers in Sri Lanka. Like biological ecosystems information ecosystems will also need time to grow and become sustainable.

Keywords

Information ecosystem, Information aggregation, Information disaggregation, Information Interdependency, Information mapping.

INTRODUCTION

There have been frequent news items highlighting problems faced by Sri Lankan farmers such as not being able to sell the harvest at a good price, under or over use of fertilizer and pesticides, not being able to get information quickly to control a spread of a weed or a pest etc. By analysing the findings from a series of interviews with farmers and Agriculture Extension Officers we discovered that the root cause for most of these problems is not being able to get the required information at the right time (De Silva et al. 2012).

Today due to advances in Information and Communication Technology (ICT) people have access to vast amount of information which they can access from any location at any time especially using mobile devices. The key purpose of information is to inform people the essential facts to support their day today activities (Davenport and Prusak 1997). Advances in technology has enabled us to access large repository of information ubiquitously. However, finding right information is still a challenging task. In agriculture domain what crops will grow in a farm or what fertilizer to be used for a crop are examples of information that can be found from books, leaflets and websites. The challenge here is to find the information that suit the context. For example, to find what crops will grow in a specific farm we need to first find the climatic conditions, soil type and type of irrigation that is relevant to “the farm” and be able to query a knowledge base using these parameters. To do this we need to disaggregate the published information and re-organise to be able to query in the context of “the farm”(Walisadeera et al. 2013c).

We also need information about rapidly changing or evolving situations. In the agriculture domain prevailing market prices, current extent of planted crops, spread of a pest or a disease are examples of such changing information. The challenge is to find ways to aggregate information provided by a sample of users to derive the overall situation (Singh and Jain 2010). Humans produce and consume different information during their personal activities or during their daily operations in an organization. There are various situations where the information produced by a group of individuals or organizations is very valuable to another individual or an organization. This creates strong interrelationships and dependencies among these people forming an information ecosystem for a given domain (Nardi and O Day 1999). Within such an information ecosystem there are producers, consumers, aggregators and decomposers. Information gets transformed when flowing through these actors similar to flow of energy in a biological ecosystem.

In our investigation of ways to enhance information flow within the agriculture domain we discovered it is possible to provide information needed by one group of stakeholders by aggregating or disaggregating information produced by some other groups or same group of stakeholders. This mapping of information consumed by a group of stakeholders to information produced by other groups of stakeholders using aggregation and disaggregation operations is a major contribution made in this paper.

In this paper

- We explain the agriculture domain in Sri Lanka, the various stakeholders and their operations within the respective stakeholder organizations.
- We list the information needs of the respective stakeholders of the agriculture domain. These were collected using stakeholder interviews and questionnaires. In addition to the information needs, we also identified the information generated by these stakeholders as part of their daily operations.
- We describe the evolution of the proposed design starting from a farmer centric information flow model to stakeholder centric information flow model. Stakeholder centric information flow model connects all relevant stakeholders to a particular stakeholder or an organization to facilitate information sharing.
- We describe how biological ecosystems inspired us to transform the stakeholder centric information flow model to an information ecosystem for the agriculture domain. We discovered the possibility of mapping information produced by one or more groups of stakeholders into information needed by another group of stakeholders by using aggregation and disaggregation operations.
- We conclude by highlighting how our discovery of creating efficient information flow patterns can lead to creating a win-win situation for people working in the agriculture domain. As for future work we propose to generalize the creation of information ecosystems to overcome information gaps that may exist in many other domains.

PROBLEM DOMAIN

Agriculture sector in Sri Lanka(SL) undergoes several issues (Bandara 2012; Berenger 2009; Hettiarachchi 2012; Hettiarachchi 2011; Rodrigo 2013) due to the lack of information sharing at the time of decision making (De Silva et al. 2012). As such we selected SL as a pilot study to identify the stakeholders and their operations within the agriculture domain. Following is a brief description of key stakeholders associated with the agriculture domain and their functions within the respective stakeholder organizations.

- **Farmer (F)** the main stakeholder of the agriculture domain engages in cultivation to nourish people in the country as well as to strengthen the economy of the country through exports. Farmers work individually or within farm clusters to produce the county's food need such as rice, vegetables and fruits.
- **Agriculture related government organizations and other research institutes** include **Agriculture Research Production Assistants (ARPA)**, **Agriculture Instructors (AI)**, **Department of Agriculture (DOA), Ministry of Agriculture (MOA)** and **agriculture related research institutes**. Some of these stakeholder organizations are responsible for generating agriculture related knowledge. Some are engaged in research leading to preparation of agriculture policies, best cultivation techniques and cultivation materials. Some stakeholder organizations are mainly responsible for communicating these findings to the relevant stakeholders. For example, DOA is responsible of generating agriculture knowledge for the farmers and other officers within the agriculture field, whereas, ARPA's and AI's are responsible for communicating this knowledge to the farmers. These stakeholder organizations are also responsible for aggregating cultivation data for the purpose of reporting other relevant stakeholder groups to make better decisions (for example how much to import, how much to export, whether to impose an import tax to reduce imports for the betterment of farmers etc.).
- **Agro chemical companies and seed importers (CH)** engage in selling agriculture products to farmers including agrochemicals, fertilizer, agro equipment, seeds and planting materials. They also provide other services such as advisory, laboratory and personal loans for the respective stakeholders.
- **Buyers (B)** are another category of stakeholders within the agriculture domain. In SL, private companies, retailers, middlemen, wholesalers and consumer are the main operating stakeholder groups in this category. They engage in buying cultivation products from the relevant stakeholders.
- **Financial institutions (MF)** also operate actively within the agriculture sector by providing financial assistance to different stakeholders. Personal loans, organizational loans, various equipment loans and

insurance schemes and micro-financing are among some of these functions provided by these stakeholders.

- **Meteorology (M)** observes and collect weather related data to provide services relevant to meteorology. They also engage in varies research activities in meteorology and climatology. They issue early warnings and advisory services to public in relations to sudden weather and climatic changes.

During our field visits and discussions we identified that these stakeholders depend on the information produced by other stakeholders in the agriculture domain.

STAKEHOLDER INFORMATION CONSUMPTION AND PRODUCTION

We gathered the information needed and generated by above stakeholder groups using questionnaires, formal and informal interviews. Questionnaire consists of questions (Q1 to Q5) which aimed at identifying at least one aspect as shown in Table 1.The questionnaire is given in appendix 1.

Table 1. Questions vs. Aimed Aspects

Aspect	Q1	Q2a	Q2b	Q2c	Q3	Q4	Q4a	Q4b	Q5
Identify the information need among stakeholders of the agriculture domain	√	√			√				
Determine any current issues / difficulties in getting the information			√	√					
Identify the information generated among stakeholders of the agriculture domain						√	√		
Determine any existing conditions in sharing information relevant to stakeholders/agriculture.						√		√	√

Below we explain our findings.

Information Needs

All stakeholders within the agriculture domain need information. Information needs are categorized into two categories; static and dynamic. Static information represents stable knowledge whereas dynamic information represents the information that changes over time. Table 2 lists the information needs that we identified during our formal and informal discussions among the stakeholders of the agriculture domain.

Farmers need information to make better decisions throughout their farming life cycle (Lokanathan and Kapugama 2012). Crop planning, seeding, planting, growing, harvesting and selling are the main stages of farming life cycle. Farmers need static information such as higher yield crops, varieties, crop diseases and best farming techniques to better manage their crops. Aggregated dynamic information such as planned crop extent, cultivated crop extent and harvest are some valuable information for farmers in decision making. Knowing the planned crop extent in prior will aid the farmer to avoid growing the same crop that the majority of the farmers are growing in a specific cultivation region. Similarly, knowing the aggregated harvest details for crops such as onions that can be kept in storage for a while can be used to decide when to take the harvest to the market to get a good price. In the absence of these important aggregated information farmers currently face several issues at the time of crop selection and selling.

Currently, ARPAs meet famers in a particular ARPA division on a monthly basis to gather data relevant to their cultivation stages. They need this information to calculate the aggregated monthly statistics on the cultivation extent and other issues such as harvest losses, pest and disease outbreaks. AIs further aggregate these statistics by combining several ARPA divisions. As such both ARPAs and AIs need information on the constantly changing status of farms (dynamic information) in the allocated area to produce and present more accurate information to the higher authorities. Further, immediate updates on some of the issues are also essential for these people to respond quickly rather than discovering the issues in their routing monthly field visits. They also need static information as shown in Table 2, to engage in various advisory services to provide a better service. DOA prepares various reports using the aggregated information for various decision making committees. Thus, they also require information as shown in Table 2 to aggregate data covering the entire country. They require information on the aggregated seed or fertilizer requirements, outbreak of diseases and pests to engage in various activities. Information on available agro-chemical companies and seed importers will aid them to inspect their selling products to manage the quality of their services.

Table 2. Stakeholder Information Needs

Stakeholder	Information Needs	Static / Dynamic
F, ARPA, AI	Suitable crops and varieties	Static
F, ARPA, AI	Possible pest, diseases and treatments	Static
F, ARPA, AI	Best cultivation techniques	Static
F, ARPA, AI	Fertilizer usage	Static
F, ARPA, AI	Field establishment techniques	Static
F, ARPA, AI	Pest management techniques	Static
F, ARPA, AI, DOA	Market prices	Dynamic
F, ARPA, AI, DOA	Water availability	Dynamic
F, ARPA, AI, DOA	Seed suppliers	Dynamic
F, ARPA, AI, DOA	Subsidiary offers	Dynamic
F, ARPA, AI, DOA, MOA, CH	Aggregated planned crop extent	Dynamic
F, ARPA, AI, DOA, MOA, CH, B	Aggregated cultivated crop extent	Dynamic
F, ARPA, AI, DOA, MOA, B	Aggregated harvest details	Dynamic
ARPA, AI, DOA, MOA	Aggregated harvest losses	Dynamic
ARPA, AI, DOA, MOA, CH, B	Aggregated pest and disease outbreaks	Dynamic
DOA, MOA, CH, B	Aggregated seed requirement	Dynamic
DOA, MOA, CH, B	Aggregated fertilizer requirement	Dynamic
F, ARPA, AI, DOA, MOA	Agro-chemical suppliers	Dynamic
DOA, MOA, CH	Aggregated Pesticides requirement	Dynamic
ARPA, AI, MF	Aggregated Farm details	Dynamic
DOA, MOA, MF	Loan requests	Dynamic

Agro-chemical companies and seed importers also require aggregated information to reduce the unnecessary costs and increase their revenue. Further, knowing their requirements (individually or as an area) enable them to directly contact the relevant stakeholders for selling their products. Moreover, they also require new findings and recommendations proposed by DOA to increase their quality in providing services.

Buyers on the other hand may also render several services to the farmers in providing seeds, fertilizer and loans. Thus they also require similar information as shown in Table 2. On the consumer end they need information on current cultivation statistics to contact farmers directly to source special food requirements of consumers.

Information Generated

Information identified in Table 2 are generated within different stakeholder/stakeholder groups. Farmer generates information on current cultivation status of their farms (planned cultivation extent, cultivation extent, harvesting period, seed requirement, and damage extent). The DOA and other research institutes produce valuable information on new crops/varieties, new cultivation techniques, best fertilizer requirements and policies related to agriculture matters. Agro-chemical companies and seed importers generate information on agro-products such as hybrid seeds, fertilizer and equipment. They also generate information on various other services rendered for relevant stakeholders such as laboratory facilities and loans. Buyers on the other end generate vital information on food demand within the country. Financial institutes that offer loans for various purposes generate loan specific information required by the stakeholders in the agriculture domain. Weather related reports and sudden climatic changes are some of the important information produced by the Meteorology department. These are of immense value for the stakeholders such as farmers and other agriculture related government institutes as they mainly operate and make decisions based on weather and climatic conditions.

Current Issues and Constraints in Information Sharing

At present most of the stakeholders obtain the required information with difficulty. Even the static information required by various stakeholders is gained through workshops and direct communications with the relevant stakeholders. Farmers mostly obtain information or advice through direct contact with fellow farmers, ARPAs and AIs. Occasionally they visit agriculture related institutes such as DOA to obtain information and other services. However, due to high travelling cost very few use this approach to get information. ARPA's and AI's also find it difficult to visit farmers on a regular basis to provide relevant agriculture knowledge and advices due to the large number of farmers allocated per ARPA and AI. Accessibility problems and bad road conditions act as further barriers. Furthermore, in the current process there is a long delay in communicating the knowledge produced by research institutes to the relevant stakeholders.

Dynamic information collected at present is not flowing properly from the relevant stakeholders to the stakeholders who need this information. Even the collected information by ARPAs is not properly communicated to the corresponding AIs. The aggregated statistics are not shared among the stakeholders such as farmers. Accuracy of these statistics may also vary within the recorded time period. The cultivated extent could vary due to crop damage or outbreak of a pest or a disease. Yet authorities tend to make decisions based on submitted records where these immediate occurrences are not getting reflected.

Making use of advances in ICT, there are informative websites to provide agriculture knowledge for the stakeholders of the agriculture domain (Audio Visual Center Department of Agriculture ; Department of Agriculture 2006). These websites contain large amount of static information. However, every few get the benefit from these websites. Lack of resources and computer literacy are the causes for the low usage of these websites among the farming communities. We also observed that these websites are not catering the actual information needs of the respective stakeholders. These provide very general information and not customised to suit stakeholder's specific context.

Based on the above findings we derived the following observations.

- Most of the time the stakeholders work in isolation within their own stakeholder organizations to perform their functions. However, to attend and make proper decisions in their daily operations, the stakeholders require considerable amount of information. The required information either is generated by their own stakeholder organization or by other relevant stakeholder groups.
- The stakeholders generate significant amount of important information that is very valuable to other stakeholders in the agriculture domain. Currently, the value derived from this information is insignificant as these were not properly utilized for decision making purposes by the relevant stakeholder categories.
- Currently, interdependent stakeholders communicate directly via face to face or through mobile or land phones.

Based upon the above observations we identified that there is an information imbalance within the agriculture domain in SL due to not having an efficient information flow model.

EVOLUTION OF THE INFORMATION FLOW MODEL

Farmer Centric

Our early studies were centred on the farmers' information needs. Farmer needs information as mentioned in the above section. We designed a farmer centric information flow model (De Silva et al. 2012) to provide the necessary information to the farmer. For this, we identified the important stakeholders who generate the information required by the farmers. We designed and developed the artefact on a mobile platform and tested among the farming communities. More information on the artefact can be found on (De Silva et al. 2013). This artefact enabled us to identify the means of providing the required information for farmers. We further observed the farmer willingness in getting the required information and sharing the information such as planned and cultivated crop extent with other farmers using the artefact. The farmer centric information flow model requires information from different stakeholder groups. This led us in identifying the relevant stakeholder groups and the information generated by these people. It is important that these stakeholders willingly share up to date information to ensure information completeness and accuracy. Often people tend to share information when they get some benefit in return. We recognised that this requirement can be met by designing a stakeholder centric information flow model for the agriculture domain.

Stakeholder Centric

Every stakeholder in the agriculture domain needs information either produced by other stakeholder organizations or within their own stakeholder organization. For example, DOA needs information gathered by ARPA's and AI's to produce aggregated information on cultivated land extent, damaged crop extent and expected harvest. They also require relevant information on pest, disease attacks and affected areas. This information will lead the relevant stakeholders to better manage and advise farmers on various precautions. Further, they require information on agro-chemical companies and seed importers to increase the transparency and to give a better service for the agriculture domain.

Thus, for each stakeholder we can identify other stakeholders that produce information that they need. From stakeholder to stakeholder information needs vary. As such to cater for their information needs they are required to connect to different groups of stakeholders. All relevant stakeholders should be connected to a particular stakeholder (Stakeholder i to n) or a stakeholder organization (stakeholder j) as shown in Figure 1. Further, stakeholder i may need information generated by the same category of stakeholders (Stakeholder i). Linking these stakeholders in a systematic way will create a stakeholder centric information flow model. This way we can reduce the time and cost in getting the necessary information by different stakeholders.

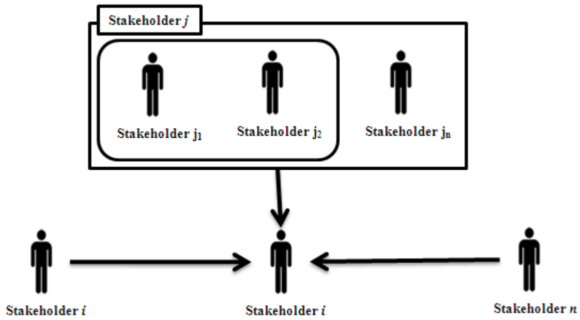

Figure 1: Stakeholder Centric Information Flow Model

TOWARDS AN AGRICULTURE INFORMATION ECOSYSTEM

Stakeholder centric model is workable where the relevant stakeholders' willingly share the information that they produce (Constant et al. 1994; Jarvenpaa and Staples 2001). There are many factors governing the information sharing behaviour of an individual (Ford and Staples 2008). If information generates a good outcome not only for themselves but also for others in an organization, may have a positive impact on the likelihood of sharing information (Constant et al. 1994). Prior research has also demonstrated that factors such as individual motivation (Wasko and Faraj 2005), potential benefits (Ford and Staples 2008), trust (Jarvenpaa et al. 2004; Jarvenpaa and Staples 2001) and ownership (Jarvenpaa and Staples 2001) can create a tendency in sharing information.

In the agriculture domain, the stakeholders could be rewarded by providing direct and indirect benefits for what they share. Monetary rewards such as increase in revenue and reduction in costs are considered as direct benefits. Other benefits such as increase in self-esteem, citizen empowerment are considered as indirect benefits. Some stakeholders such as meteorology in the agriculture domain may not receive any direct benefits as they do not require any information generated by other stakeholders for their daily activities. Instead they will be rewarded by indirect benefits such as good reputation for better prediction. In illustrating a direct benefit, farmer in a particular region sharing the current cultivation quantity with respect to a particular crop can gain monetary rewards as this could be aggregated with the similar corresponding data to produce the total cultivation quantity of that crop in that particular region. This will facilitate to gain an understanding of the current cultivation percentages of the same crop grown by farmers in a particular region. If this percentage is high farmer is able to switch to another crop, thus avoiding an oversupply scenario. Consequently, this would mitigate the problems that the farmer would experience at the time of selling, thus improving the financial state of the farmer. Based upon these findings we designed an information ecosystem for the agriculture domain in Sri Lanka as shown in Figure 2. By collaborating with this model stakeholders get access to information easily as it links all relevant stakeholders, thus facilitating faster decision making.

Information shared by each stakeholder can be consumed by others either directly or through processing using aggregation or disaggregation methods. This interdependency in information production and consumption demonstrates important characteristic of an information ecosystem (Briscoe 2010; Stanley and Briscoe 2010). Figure 2 is an illustration of this concept achieved through a social life network (SLN). Social life networks are next generation of mobile based social networks where both people and resources get interconnected to obtain information for their daily activities (Jain R. and Sonnen 2011). As illustrated in Figure 2 stakeholders will share the information they produce as inputs to the SLN. In return they will obtain information that is further processed within the SLN to provide stakeholders with direct and / or indirect benefits.

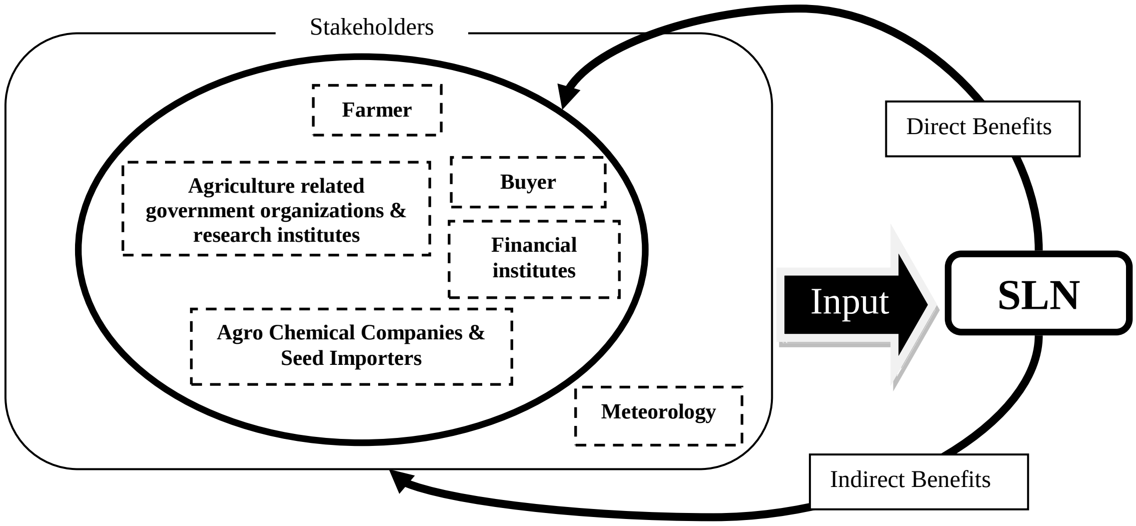

Figure 2: Information ecosystem for the Agriculture Domain

Biological vs. Information Ecosystem

Information ecosystem consists of people (e.g. stakeholders) and the environment (domain specific resources) in a particular local context (Nardi and O Day 1999). Similar to biological ecosystem, information ecosystem demonstrates strong interdependencies among people and the environment. Thus, an imbalance of any part of the information ecosystem will cause an impact on its equilibrium as in a biological ecosystem. The information ecosystems are information centric whereas the biological ecosystems are energy centric (Stanley and Briscoe 2010).

The information ecosystem presented in this paper produces information needs of the stakeholders by mapping the information produced by others. Similar to a biological system we used aggregation and disaggregation methods to derive useful information required by stakeholders. In information ecosystem aggregation methods such as summing, grouping, merging etc. can be used to combine information produced by different stakeholders to generate needed information. Disaggregation on the other hand is similar to function done by decomposers in a biological ecosystem. They decay the dead organisms or non-living organisms to much smaller parts that can be consumed by others to obtain energy. As such within the information ecosystem disaggregation methods will break large chunks of information into smaller parts so that this information can be queried in context. In our system this was achieved by designing a user centred ontology for the agriculture domain and creating an ontological knowledgebase to store prior created information relating to Sri Lankan agriculture that can now be queried in user context (Walisadeera et al. 2013a; Walisadeera et al. 2013b).

Information Mapping

For each stakeholder within the agriculture domain, we identified their information inputs based on what information that they produce and information needs based on that they consume in their daily operations. Then we created a mapping to identify the stakeholders responsible for producing needed information. This mapping illustrated the interdependency among several stakeholders in the agriculture domain. Further we identified the operators to demonstrate how this mapping could be achieved.

Below we illustrate a small sample of farmer information inputs. Farmer information inputs are the information generated as a result of their daily tasks as shown in second column in Table 3. A code is used to uniquely identify the relevant stakeholder. The letter “I” denotes the information input and each input is represented using a sequence number.

Table 3. Farmer Information Inputs

Code	Information Input	Parameters
F_{I1}	Expected Crop to Grow	Crop, Variety, No of Acres, Planned Month
F_{I2}	Cultivated Crops	Crop, Variety, No of Acres, Planted Date, Harvest Date
F_{I3}	Damaged Crop Information	Crop, Variety, Damaged Acres, Damage Reason
F_{I4}	Affected Pest & Disease Information	Crop, Variety, Pest/Disease, First Affected Date
F_{I5}	Seed Requirement	Crop, Variety, Quantity
F_{I6}	My Offerings_Yield	Crop, Variety, Quantity, Price

Similar to the sample presented in Table 3, we identified possible information inputs from every stakeholder in the agriculture domain. In this tabular form the third column lists the parameters that need to be captured. For example, when a farmer starts cultivating a crop he is capable of providing values to the parameters crop, variety, number of acres, planted date and the expected harvesting date. Next, we identified the information needs of the stakeholders. We also identified the stakeholders who are generating this information. From this we derived the existing dependencies among stakeholders. Then by applying aggregation or disaggregation methods we have formulated a way to compute information needs. An example of this information mapping to meet farmer information needs is shown in Table 4. Below we explain three instances to illustrate how we have generated the information needs through information mapping.

Table 4. Farmer Information Needs

Code	Information Needs	Mapping	Operators
F_{O1}	Aggregated Planned crop extent	F_{I1}	Aggregate : {Group by{DS}, SUM{F_{I1}}, Output{DS, Crop, No of Acres}}
F_{O2}	Aggregated Cultivated crop extent	AR_{I3}	Aggregate : {Group by{DS}, SUM{AR_{I3}}, Output{DS, Crop, No of Acres}}
F_{O3}	Aggregated Harvesting details	AR_{I3}	Aggregate : {Group by{DS}, SUM{AR_{I3}}, Output{DS, Crop, Expected Harvest}}
F_{O4}	Agriculture Knowledge on crops and variety	DOA_{I1}	Disaggregate: {Filter {Agro Zone}, Output{Crop, Variety, special features}}
F_{O5}	Seed / Planting material information	F_{I6}, DOA_{I5}, CH_{I1}	Aggregate : { Merge{F_{I6},DOA_{I5}, CH_{I1}}, Sort{Agro Zone}, Output{Crop, Variety, Rate, Price, Supplier}}
F_{O6}	Agriculture Knowledge on Fertilizer requirements	DOA_{I3}, CH_{I2}	Disaggregate / Aggregate: {Filter {Agro Zone, Crop/Variety} , Merge {DOA_{I3}, CH_{I2}}, Output{Crop, Variety, Fertilizer, Amount}}

Farmer needs information on aggregated planned crop extent (F_{O1}) to avoid potential over production situations. Letter O denotes the information needs. In order to calculate this aggregated value, we need information on the expected crop that the farmer is going to grow in the following month or season. This input is generated among farmers as “Expected crop to grow” (Denoted by F_{I1} in Table 3). We aggregate this input to produce the aggregated planned crop extent. As such F_{O1} will get generated by applying operators, namely group and sum. First, farmer input is grouped by the relevant District Division (DS). Next the grouped statistics are summed to calculate the aggregated planned crop extent to provide information on DS, crop and the number of planned acres to be cultivated. However, to produce more accurate statistics these operators will be further subjected to predictive modelling and sampling theory techniques.

Farmers need agriculture knowledge on suitable crops and varieties to plan their cultivation. This information need is denoted by F_{O4} in Table 4. DOA in SL generates information on suitable crops and varieties (DOA_{I1}). This information is a direct input for the agriculture ontology. Information on the ontology is queried and disaggregated using the filter operator to provide information on suitable crops based on the agro-zone.

In some cases we also need to apply both aggregation and disaggregation methods to generate one’s information need. Agriculture information on fertilizer requirements (F_{O6}) is generated by applying both aggregation and disaggregation. First the information is disaggregated using filter operator on the parameters agro-zone, crop/variety. Agriculture knowledge on fertilizer is managed by both DOA and agro-chemical companies. Thus, to present the information need both inputs coming from DOA (DOA_{I3}) and agro-chemical companies (CH_{I2}) are merged to present the potential fertilizer amount.

CONCLUSION AND FUTURE WORK

Stakeholders in a domain, produce valuable information as part of their daily routine activities that are required by other stakeholders. It adds more value when this information is aggregated with other useful information or disaggregated to cater for one's information need in a specific context. However, the value that can be derived from information is very low if it does not reach the right people at the right time. Often the interdependency that exists in a domain among information production and consumption is not visible on the surface. In this research we discovered a potential mapping between information needs of stakeholders to information produced by other stakeholders in the agriculture domain by using aggregation and disaggregation operators. Based on this we derived an information flow model for agriculture domain that could be implemented using Social Life Network; next generation mobile based Social Networking system. Such a system could greatly enhance the value of information generated by stakeholders as part of their daily activities.

We saw a strong similarity between the information flow model we discovered and biological ecosystems. A biological ecosystem is a community of living organisms (plants, animals and microbes) in conjunction with the nonliving components of their environment (things like air, water and mineral soil), interacting as a system linked together through nutrient cycles and energy flows. It also contains aggregators and disaggregates (or decomposers) to match energy generation and consumption patterns. Such as biological ecosystems the information ecosystems will also need time to grow (Nardi and O Day 1999). Thus we belie the Social Life Network that we will be deploying based on this information ecosystem model will also grow with time and evolve into a sustainable model.

As future work we plan to test this model in other domains such as healthcare, fisheries, manufacturing etc. Based on the findings we plan to develop a generalized information ecosystem model to enhance flow of information in any domain to address the information imbalance and enhanced the value of generated information as part of daily activities.

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APPENDIX 1

Q1	Do you / your organization currently deal with any of the following stakeholders in the agriculture domain to obtain information relevant to stakeholders / agriculture? (Farmer / Agriculture related government organizations / Agro Chemical Companies and Seed Importers / Buyers / Micro-Finance Institutes / Meteorology / Others)
Q2a	Please specify the stakeholder / agriculture related information that you / your organization currently getting from the above mentioned sources?
Q2b	How do you /your organization currently obtain the above mentioned information?
Q2c	Have you/your organization experience any issues/difficulties in getting the above mentioned information?
Q3	What (additional) information would you/your organization like to receive from such stakeholders in the agriculture domain?
Q4	Do you/your organization generate any information that will aid the stakeholders in the agriculture domain? (Yes and willing to Specify / Yes but unwilling to Specify / No such information)
Q4a	If you tick "Yes and willing to specify" Please specify the information generated relevant to stakeholders of the agriculture domain.
Q4b	If you tick "Yes and unwilling to specify" Please specify any specific reasons for the unwillingness. Do you think that any other person/organization is responsible for specifying this information?
Q5	Would you/your organization like to share the above mentioned/unmentioned information within the stakeholders of the agriculture domain? (Please Specify)

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