ASSESSMENT OF LINKAGES AND INFORMATION FLOW IN THE AGRICULTURAL INNOVATION SYSTEM IN THE NEW VALLEY GOVERNORATE, EGYPT

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ABSTRACT

The purpose of this study was to 1) assess the linkages in the New Valley's Agricultural Innovation System (NVAIS) and 2) characterize the information structure underlying the system. Data were collected from 50 respondents represent the nine components of the studied system during the period from Feb. to Mar. 2015 using in-depth interviews. The graph theoretical technique (GTT) was used to assess the linkages and information structures in the studied system. The obtained results showed that NVAIS was not fully identified; however, 44 of a total 72 linkages only were identified, and have a density of 0.61. Only 14 linkages are established through specific linkage mechanisms so density declines to 0.19. The component "Observatory of Development and cooperatives (O)" is by far the main sender of information, followed by the component "Extension (E)" and "Higher Education (H)". The main receivers of information, is the component of "Farmers (F)". Components of "Research (R)" and "Policy (P)" have a special position in this system, being the most interactive components as it sends as much information as it receives from others. Components of Secondary agricultural schools (S) and Agricultural Credit (C) are candidates to reform because of they interacts other components at a low tone. The component of private input supply, marketing and processing (M) is isolated is needs to deal efforts on enhancing its interaction within other components of the system. Any interventions on the components of O or F will be reflected in all over the system because the first one is a dominant component while the second is subordinate. The intermediary institutions, O and E, should play a more active role in bringing together other components. Specifically, links between these components could be strengthened through policy dialogues where the O and E could pass information from S, F, M, and C to P, H and R; such transmission of information should help P, R and H reassess agricultural policy, research and education priorities.

INTRODUCTION

Farming is a knowledge-intensive industry; farmers need to obtain and process financial, climatic, technical and regulatory information to manage their farms. Both public and private institutions have emerged to supply farmers with information and analysis **(Just and Zilberman, 2002).** Agricultural development depends on a great extent on how successfully knowledge is generated and applied, and indeed knowledge-intensiveness has featured prominently in most strategies to pro-

mote agricultural development (**Rajalahti et al 2008).**

Investments in agricultural research and knowledge generation have been strong components in strategies to promote sustainable and equitable agricultural development. The context for this investment has evolved over time. During the 1980s, agricultural research focused on strengthening the research supply system at both international and country levels, this view is usually termed the national agricultural research system (NARS). During the 1990s, the focus shifted to improve the links between research, education and extension together with identifying farmers' needs for research, this view was termed as the Agricultural Knowledge and Information System (AKIS). However, during both decades the links remained linear with research knowledge generated for extension, which was expected to transfer new technologies to farmers. More recently, the focus has changed, as it became apparent that the supply and demand for knowledge was far more complex that the linear approaches implied. It was increasingly realized that an approach involving many stakeholders was needed to speed the use of knowledge for income generation. This has come be known as an Agricultural Innovation System (AIS) approach. The approach embraces the totality of interactions between stakeholders required to encourage the use of research products for innovation that will benefit a wide range of actors (**Rivera, 2006; World Bank, 2007 and Rajalahti et al 2008).**

The AIS framework was developed in the 1990s, based on the National Innovation System (NIS) industrial approach, which emerged in evolutionary economics and gained wide acceptance in science policy in industrialized countries at that time. By the 2000s, the AIS framework started to gain increasing attention in the international development community. While stressing the need for linkages, AIS has moved innovation to the center of attention and stressed a wide range of stakeholders and pluralistic networking among agriculturally relevant institutions (**Rivera et al 2006).**

The innovation system in agriculture is critical to shifting socio-economic research beyond technological change "induced" by the relative prices of land, labor and other production factors in agriculture; beyond the concept of linear technology transfers from industrialized to developing countries, from advanced and international research centers to national systems as an engine of change (**Speilman, 2005).** It extends beyond the creation of knowledge to encompass the factors affecting demand for and use of knowledge in novel and useful ways (**World Bank, 2007).** The AIS is a set of agents i.e., farmers' organizations; input suppliers, processing and marketing enterprises; research and education institutions; credit institutions, extension and information units, private consultancy firms, international development agencies, and the government, that contribute jointly and/or individually to the development, diffusion and use of new agricultural technologies, and that influence directly and/or indirectly to the process of technological change in agriculture system (**Temel et al 2002b).**

A system is a set of agents or institutions established around a common goal. It characterized by: 1) it must have a goal determining the type of institutions or agents to be included within the system. It should capture only those interactions related to the predetermined goal, 2) all the interactions within the system should be expressed in a common unit of measure, and 3) influence as an agent on itself and others must be bounded (**Temel, et al 2002a).**

The system approach is crucial in identifying economic, social, political, organizational, institutional activities and functions of the AIS. These activities are conducted by sets of agents that interact to achieve a common goal through exchange of information and by learning from each other (**Arumapperuma, 2005).** Two convictions drive the current study. First, that innovation (new ideas, new knowledge) occurs almost everywhere in society. Second, that innovation is largely the result of a complex set of relationships between agents who produce, distribute, and apply various kinds of knowledge (**Temel et al 2002a).** The innovation system perspective is fast a popular approach in the study of how society generates, disseminates, and utilizes knowledge, and how such systems can be strengthened for greater social benefit (**Speilman, 2005).** Furthermore, practitioners require information for short- and long-term decision making and for managing limited resources effectively within complex, nonline-

ar processes of technical and institutional change within the AIS **(World Bank, 2012).**

Figure (1) presents a simplified conceptual framework for the AIS. The figure shows the main actors (typical agricultural knowledge and technology providers and users, as well as the bridging or intermediary institutions that facilitate their interaction); the potential interactions between actors; and the agricultural policies and informal institutions,

attitudes, and practices that either support or hinder the process of innovation **(World Bank, 2012).**

The concept of innovation systems rests upon the premise that understanding the linkages among the actors involved in innovation is a key for improving technology performance. Innovation and technical progress are the result of a complex set of relationships among actors producing, distributing and applying various kinds of knowledge **(OECD, 1997).**
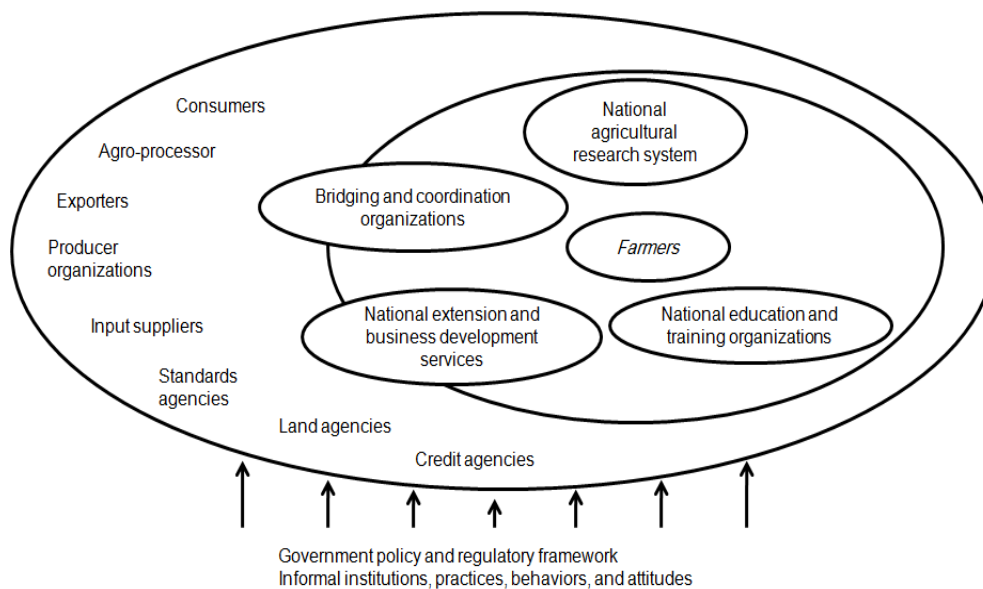

Figure 1: The conceptual framework of the agricultural innovation system

Source: **World Bank (2012).**

Actors in an AIS innovate, not in isolation, but through interacting with other actors—farmers, firms, farmers' organizations, researchers, financial institutions, and public organizations—and the socioeconomic environment. Their interactions take different forms, such as consultations to define innovation policies, joint research activities, or participation in or facilitation of innovation networks and value chains, while the lack of appropriate coordination and governance for agricultural innovation at the national level is a chronic problem in many countries. Better coordination can improve the design and implementation of innovation policies by allow-

ing more actors to voice their needs and concerns, resulting in more inclusive policies and faster diffusion of innovations. Stronger interaction and coordination can also induce all actors in an innovation system, particularly public research and extension organizations, to be more aware of and responsive to the needs and concerns of other actors, especially resource-poor households **(World Bank, 2012)**.

The AIS concept is attractive not only because it offers a holistic explanation of how knowledge is produced, diffused, and used, but because it emphasizes the actors and processes that have become increasingly im-

portant in agricultural development **(World Bank, 2007).** The remarkable notice is, inadequacies in this system, such as the inability to consistently provide accurate, timely and easily accessible information, present several challenges to farmers **(Just and Zilberman, 2002).**

The innovation systems approach reflects the increasing attention given to the economic role of knowledge. Here, the emphasis is on mapping knowledge flows as a complement to measuring knowledge investments. These flows, particularly of knowledge "codified" in publications, patents and other sources, are both increasing and becoming easier to detect due largely to information technology **(OECD, 1997).**

The process of technological innovation involves interactions among a wide range of actors in society, who form a system of mutually reinforcing learning activities. The concept of a system offers a suitable framework for conveying the notion of parts, their interconnectedness, and their interaction, evolution over time, and emergence of novel structures **(Juma, 2011).** As economic activities become more knowledge-intensive, a large and growing number of institutions with specialized expertise of very different kinds are now involved in the production and diffusion of knowledge. The determinants of success of enterprises, and of national economies, are ever more dependent on their effectiveness in gathering and utilizing knowledge from these institutions **(OECD, 1997).**

Better-connected actors with stronger innovation capabilities help to solve coordination problems among potential partners, build trust for collaboration, build up innovation capabilities, and develop a better understanding about the needs and capabilities of other actors in the AIS, especially marginalized groups. Other economic benefits of coordinating more capable actors include the following **(World Bank, 2012):** 1) Lowering the cost of searching for and using technical and commercial information, easing the identification of emerging technical, social, and economic needs and opportunities, facilitating experimentation on alternative solutions, opening market opportunities, and developing competitive capabilities, 2) Integrating more effectively into innovation networks, 3) Developing new skills and more effectively using human,

social, physical, and financial resources, thus fostering economic growth, and 4) Participating in the development and diffusion of innovations, including action-research projects and new approaches to extension.

As a result, bringing together the diffuse elements of a collective system of knowledge creation and use should significantly improve the innovation performance of a country, as well as the organization's capacity to receive information, to share it with others and to learn from it are assumed to be the key factor that shapes the flow patterns and the performance of the innovation system concerned **(Temel, 2007).**

OBJECTIVES

The processes, dynamics and relationships at work between organizations and individuals of any AIS are complex. The problems that organizations seek to address inevitably involve multiple interests, and these interests are often represented by a multiplicity of organizations. Moreover, interactions between knowledge-generating and knowledge-using agents are important as direct investment in R&D. The system approach is a systemic method to present qualitative information about such interactions and information flow within the system. Based on that, this study aimed to:

1) Assess the linkages in the New Valley's Agricultural Innovation System (NVAIS), and

2) Assess the information flow in a certain system.

METHODOLOGY

The study adopted the Graph-Theoretical Technique (GTT), which was developed and applied by **Temel & Maru (2002); Temel et al (2002 a & b; 2003); Temel (2007) and Temel & Kinlay (2012)** to assess the linkages and information flow in the studied system. The GTT is combines two fields of research: a) systems analysis in engineering and b) graph theory in discrete mathematics. The graph theory offers useful techniques and concepts that can be used in assessing properties of a system quantitatively; several graphs theoretical concepts are borrowed from discrete mathematics, and modified in

such a way to reflect the specificities of the system under investigation **(Temel et al 2002a: 4).** The GTT include several steps starts with optimal system matrix passes through a coded linkages matrix, a refined matrix, adjusting matrix, cause-effect structure of adjusted matrix, and mechanisms matrix and ends with density of the system

The New Valley governorate is located in the south west part of western desert of Egypt. It has local borders with governorates of Menia, Giza, and Matrouh from the north; Assiut, Sohag, Qena, and Aswan from the east; and country borders with Libya from the West and Sudan from the South. It represents about 44% from the total area of Egypt, and 67 % of the total area of Egyptian western desert, with five districts namely: Kharga, Dakhla, Frafra, Paris, and Balatt.

The New Valley's Agricultural Innovation System (NVAIS) is represented by nine main components namely: 1) The Policy (P) component includes government representatives (executives), 2) The General observatory for development and cooperatives (O) component responsible for lands of the national project of young graduates and beneficiaries, 3) The Research (R) component consists of two public research stations, one for Agricultural Research Center (21 research staff) and the other one for Desert Research Center (3 research staff), 4) The Secondary Technical Education (S) component includes five secondary agricultural schools (63 class room, 204 teachers, 94 employees), 5) The Higher Education (H) component consists of one faculty of agriculture belonging to Assiut University (45 faculty staff), 6) The Extension and information (E) component comprises public extension organization (121 extension personnel), 7) Farmers and farmers' organizations (F) component (23594 landholders with 193077 feddans and 56 agricultural cooperatives), 8) The private input supply, marketing and processing (M) component includes several private input supplier, agricultural processing firms, and traders, and 9) The Agricultural Credit (C) component, consists of 11 village banks for development and agricultural credit (172 employers)

In-depth interviews were made with fifty respondents for data collection during the period from Feb. to Mar. 2015. Of the 50 respondents; eight represents component P

(governmental executives of the other 8 components), three represents O; 4 represents R; 5 represents S; 5 represents H; 6 represents E; 10 represents F; 4 represents M; and 5 represents C.

The index of interviews includes two sections
1) To assess linkages in the system: questions on how strengths of linkages that the organization has with the rest of other organizations in the system. Respondents, who decide that their organizations have linkages with other components within the system, were asked to provide their opinions on the type of these linkages. The answers of the questions are all expressed in scales on the basis of none, weak, medium and strong linkages, and on the basis of formal, informal, and mixed type of linkages. Then, respondents, who decided that their component has a medium strength or strong linkages with the rest of other components in the system, were asked to determine the mechanisms of these linkages. The most frequent responses (mode) for each question are used in assessment of linkages within the system.
2) To assess information flow through the system: questions on: a) the organization's capacity to receive new information from others, b) its capacity to learn information (capacity to integrate new and existing information, to accumulate the new information, to accumulate its existing information, and to marginalize all types of information), and c) its capacity to share information (capacity to share the newly produced information, to transmit the new information, to advertise its own existing information, and to hide its information). Responses are expressed in scales based on none, weak, medium and strong capacities. The averages of responses are used in assessment of capacity of information flow of each component.

RESULTS AND DISCUSSIONS

Results of the study could be divided into three main heads as follows: 1) a description of the strength, types, and mechanisms of linkages in the NVAIS, 2) assessment of sys-

tem's linkages and 3) assessment of information flow through the system.

1. Description of linkages within the system

Respondents were asked to assess strength and types of linkages between their organizations within the rest of the organizations in the system. The answers to the questions are all expressed in scales on the basis of none (*n*), weak (*w*), medium (*m*) and strong (*s*) linkages, and on the basis of formal (*f*), informal (*i*), or mixed (*m*) type of linkages. Relations between these components are placed in the **Table 1,** where *fw* stands for a formal-weak linkage, *fm* formal-medium, *fs* formal-strong, *iw* informal-weak, *im* informal-medium, *is* informal-strong, *mw* mixed-weak, *mm* mixed-medium, *ms* mixed-strong and *n* stands for not existed linkages. When policy denoted by P, general observatory by O, research by R, secondary agricultural education by S, higher agricultural education by H, agricultural extension by E, farmers' organizations by F, private sector input supply, processing & marketing by M, and agricultural credit by C; findings in table 1 show several distinct features of the NVAIS as follows:

1) The NVAIS is not fully identified. Of a total of 72 linkages, only 44 are identified. The components S and M are mostly isolated from the rest of the system. The NVAIS is fairly flexible. Of 44 relations, 8 are formal (5 weak, 3 medium, 0 strong), 24 informal (12 weak, 10 medium, 2 strong), 12 mixed (5 weak, 4 medium, 3 strong).

2) All relations are formal and weak (*fw*) between the public components (P, O, S, E, C), while relations are mixed and mostly medium between the private components (F, M). This suggests a much stronger connection between the private components than that between the public sector components.

3) Surprisingly, informal relations are common between the public components, reflected especially by the dominantly informal relations between PR, PS, PH, PO, OH, RP, RH, RE, HP, HO, HR, HE, and ER. Equivalently important in this respect is the non willingness of (R, S, H) to develop contacts with C, which is implied by (*n, n, n*) in the last column and in the last row. Furthermore, much surprising that there are informal and weak linkages between O and E components which closely responsible for providing agricultural services to farmers.

Table 1. Strength and types of linkages in the New Valley's agricultural innovation system

Components	P	O	R	S	H	E	F	M	C
Policy (P)	-	*fm*	*im*	*iw*	*iw*	*fm*	*mm*	*n*	*fw*
General observatory for development and cooperatives (O)	*fm*	-	*ms*	*n*	*im*	*iw*	*ms*	*n*	*fw*
Research (R)	*iw*	*mm*	-	*n*	*im*	*im*	*is*	*n*	*n*
Secondary Education (S)	*fw*	*n*	*n*	-	*n*	*n*	*iw*	*n*	*n*
Higher Education (H)	*iw*	*iw*	*im*	*n*	-	*iw*	*im*	*n*	*n*
Extension (E)	*fw*	*iw*	*im*	*n*	*im*	-	*ms*	*n*	*iw*
Farmers and farmers' organizations (F)	*mw*	*mm*	*im*	*n*	*n*	*mw*	-	*is*	*n*
Private input supply, marketing and processing (M)	*mw*	*iw*	*n*	*n*	*n*	*iw*	*im*	-	*n*
Agricultural credit (C)	*fw*	*mw*	*n*	*n*	*n*	*mw*	*mm*	*n*	-

Source: the study's findings

4) The component O has one way or another developed linkages with all components within the system. Among these linkages, the strongest ones are with R and F.

2. Assessment of linkages within the system

The graph-theoretical technique is used to assess linkages in the New Valley Agricultural Innovation System (NVAIS), as follows:

2.1. The optimal matrix of NVAIS

The optimal matrix of the New Valley's Agricultural Innovation System consists of 9 components. The matrix maps all binary (or one-to-one) linkages between the components. The components are placed in the diagonal cells, and following clock-wise rotation; linkages among them are placed in off-diagonal cells of the **Matrix 1.**

$$\begin{bmatrix} \mathbf{P} & PO & PR & PS & PH & PE & PF & PM & PC \\ OP & \mathbf{O} & OR & OS & OH & OE & OF & OM & OC \\ RP & RO & \mathbf{R} & RS & RH & RE & RF & RM & RC \\ SP & SO & SR & \mathbf{S} & SH & SE & SF & SM & SC \\ HP & HO & HR & HS & \mathbf{H} & HE & HF & HM & HC \\ EP & EO & ER & ES & EH & \mathbf{E} & EF & EM & EC \\ FP & FO & FR & FS & FH & FE & \mathbf{F} & FM & FC \\ MP & MO & MR & MS & MH & ME & MF & \mathbf{M} & MC \\ CP & CO & CR & CS & CH & CE & CF & CM & \mathbf{C} \end{bmatrix}$$

Matrix 1: The optimal matrix of NVAIS

The optimal matrix of NVAIS (Matrix 1) contains three types of organizational linkages:
1) Type I, called within-component linkages, for example, those within P in the 1st row-1st column represent linkages among organizations or individuals who only deal with P.
2) Type II, called between- component linkages, for example, those between P and O denoted by PO in the 1st row-2nd column represent the linkages that P declared to have with O. Likewise, linkages such as those between O and P denoted by OP in the 2nd row-1st column represent the link ages the O declare to have with P. It is important to note that the linkages represented by PO are not necessarily the same as those represented by OP. This asymmetry should simply be attributed to the fact that components have different motivations for the start of a linkage.
3) Type III represents the linkages established between the two components through pathways of binary linkages. Consider, for instance, a pathway denoted by PORS, which can also be written as P→O→R→S. This pathway between P and S contains a sequence of binary linkages, starting with those between P and O (namely, PO), then between O and R (OR), and finally between R and S (RS). Sequencing is important because the pathway PORS would not necessarily lead to the same outcome as that of PROS. In this example, PORS and PROS are called three-edged pathways because they both contain three groups of binary linkages.

The total number of k-edged pathways within the system can be calculated by $n!/(n-k-1)!$, where n and k stand for numbers of components in the system and the number of edges in a pathway, respectively. Applying this formula, one can easily calculate, for example, the number of one-edged pathways in the NVAIS$_{[o]}$ matrix is $9!/(9-1-1)!=72$ where $n=9$ and $k=1$.

2.2. A refined linkage's matrix of NVAIS

Using the information drawn from **Table 1,** the interactions in Matrix 1 are coded on scale as the basis of 0 for absent, 1 for a weak, 2 for medium, and 3 for strong linkage. The visual format of the information in NVAIS$_{[r]}$ where white cells represent nonexistent linkages, grey cells weak linkages, black-lined cells medium linkages, and heavily dark cells strong linkages. This visual tool would help us to detect areas that strengthened for facilitating an effective and efficient flow of knowledge. This matrix will be adjusted in order to transform the linkages between components to the influences between them.

$$\begin{bmatrix} P & 2 & 2 & 1 & 1 & 2 & 2 & 0 & 1 \\ 2 & O & 3 & 0 & 2 & 1 & 3 & 0 & 1 \\ 1 & 2 & R & 0 & 2 & 2 & 3 & 0 & 0 \\ 1 & 0 & 0 & S & 0 & 0 & 1 & 0 & 0 \\ 1 & 1 & 2 & 0 & H & 1 & 2 & 0 & 0 \\ 1 & 1 & 2 & 0 & 2 & E & 3 & 0 & 1 \\ 1 & 2 & 2 & 0 & 0 & 1 & F & 3 & 0 \\ 1 & 1 & 0 & 0 & 0 & 1 & 2 & M & 0 \\ 1 & 1 & 0 & 0 & 0 & 1 & 2 & 0 & C \end{bmatrix}$$
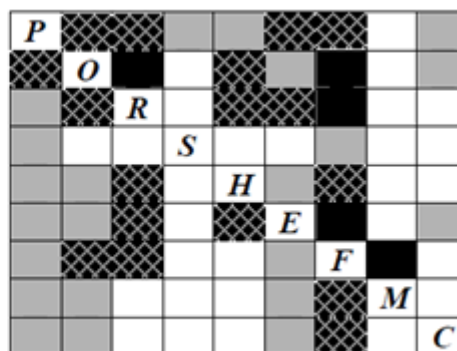
Matrix 2: The refined linkage's matrix of NVAIS and its visual format

2.3. Adjusting Matrix of NVAIS$_{[r]}$ and its Cause-Effect structure

By adjusting the refined linkages matrix of NVAIS, Matrix 2, the linkages between components are transformed to the influences between them. Depending on the degree of claimed influence, which is scaled as none ($n=0$), weak ($w=0.33$), medium ($m=0.66$), and strong ($s=1$), as shown in Matrix 3.

$$\begin{bmatrix} P & 1.32 & 1.32 & 0.33 & 0.33 & 1.32 & 1.32 & 0 & 0.33 \\ 1.32 & O & 3 & 0 & 1.32 & 0.33 & 3 & 0 & 0.33 \\ 0.33 & 1.32 & R & 0 & 1.32 & 1.32 & 3 & 0 & 0 \\ 0.33 & 0 & 0 & S & 0 & 0 & 0.33 & 0 & 0 \\ 0.33 & 0.33 & 1.32 & 0 & H & 0.33 & 1.32 & 0 & 0 \\ 0.33 & 0.33 & 1.32 & 0 & 1.32 & E & 3 & 0 & 0.33 \\ 0.33 & 1.32 & 1.32 & 0 & 0 & 0.33 & F & 3 & 0 \\ 0.33 & 0.33 & 0 & 0 & 0 & 0.33 & 1.32 & M & 0 \\ 0.33 & 0.33 & 0 & 0 & 0 & 0.33 & 1.32 & 0 & C \end{bmatrix}$$

Matrix 3. The adjusted NVAIS refined linkage's matrix

The Cause (C) is defined as the influence of a single component on each of the rests of the components in Adjusted NVAIS$_{[r]}$; and the Effect (E), as the influence of each of the rest components on that single component. These definitions, together with the clock-wise convention that was followed during the construction of the Matrix 1, imply that rows in Adjusted NVAIS matrix, Matrix 3, represent the cause, while columns represent the effect. For example, the 1st row in the Matrix 3 indicates that P influences all components except M, while the 1st column indicates all components influence P. The system cause-effect values are summarized in table 2. The value of 1.32, the arrow from P to R indicates P's influence on R. Similarly, with a value of 3, the arrow from O to R indicates O's influence on R. Hence, the total cause of P on the rest of the system is 6.27, which is the sum of the values in the 1st row of Matrix 3, and the total effect of other components on P is 3.63, which is the sum of the values in the 1st column of the matrix. The scatter plot of these coordinates in figure 2 helps identify dominant and subordinate components, as well as indicate the components that can serve as the source and the ultimate target of this knowledge.

Table 2. Cause-Effect values of the components of the NVAIS

Components	Cause (C)	Effect (E)
Policy (P)	6.27	3.63
General observatory for development and cooperatives (O)	9.30	5.28
Research (R)	7.29	8.28
Secondary Education (S)	0.66	0.33
Higher Education (H)	3.63	4.29
Extension (E)	6.63	4.29
Farmers and farmers' organizations (F)	6.30	14.61
Private input supply, marketing and processing (M)	6.30	3.00
Agricultural credit (C)	2.31	0.99

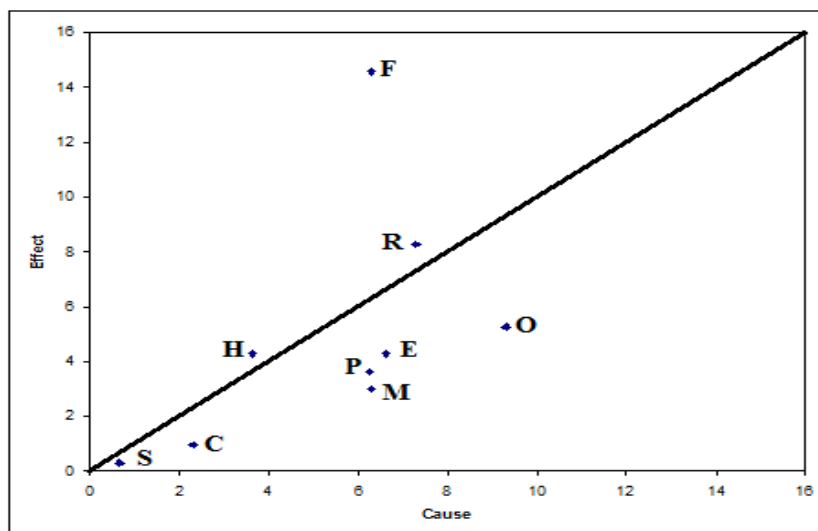Source: Estimated from the **Matrix 3.**

Figure 2. The *Cause-Effect* structure of Adjusted NVAIS[r]

The Cause-Effect structure of Adjusted NVAIS Matrix (Matrix 3) show several features as follows:

1) The component O is the dominant component, its effect on other components is much greater than others' influence on it. It could be concluded that it has considerable control over the system (or it is the key source of influence). That could be attributed to its administrative and advisory services. As well as it considered the only governmental organization responsible for development and cooperatives in the lands of the national project for young graduates and beneficiaries in the governorate. It also observes a good number of cooperatives in all villages of the governorate deal directly with farmers on one hand and with other system stakeholders in the other one. That may lead it to create linkages with other stakeholders on the system to manipulate its main role and to gain farmers' satisfaction through playing a role in solving day life problems.

2) On the contrary, the component F is subordinate; it found to be the sink of influence since it is influenced by others more than it influences them. This finding is not surprisingly, because farmers and their organizations are the final target of all components within the system, and they are the final user of knowledge.

3) Interestingly, however, R is highly interactive with the rest of the components, and is followed by H. The work nature for the components R and H, R&D, requires this high interaction with all system's components in order to be conducting in the field researches as well as applying developmental research projects.

4) Components of P, E and M still located it as the area of cause, but their influences are limited in comparison with the component O. The bad thing in this finding is low influence of the component E, public extension, which justifies its need to reform and modernization. In the other side, the lighted point of this finding is the near influence of the component M, the private sector, to the component E. It could be concluded that the private sector, component M, have values of cause-effect nearly with values for the component E which mean that it t is possible to be relied upon as a link with system components.

5) The components S and C have very low interaction with the rest of the system. That could be attributed to the absent of the actual role of these components, one of them, S, concentrates only in students and teaching processes and neglect building bridges with stakeholders. The other

one, C, suffers from many problems of isolation, and clienteles' dissatisfaction and needs to develop within the system of financing and lending.

2.4. The density of the Adjusted refined matrix of NVAIS

The density of the Adjusted Matrix denoted by d, is calculated as $d=b/[n(n-1)]$ with $1 \geq d \geq 0$, where b denotes the total number of existing binary interactions, and n is the number of dimensions of Adjusted NVAIS$_{[r]}$. A structure is remarked to be fully identified if $d=1$, which implies that all the components positively influence each other. Thus, The NVAIS is not fully identified; it has a density of 0.61, where $b = 44$ and $n = 9$. Moreover, of those 44 linkages, 22 are weak, 17 are medium strength, and only 5 are strong. That means that there is a lot of effort required to fully identify the system to increase its density within the system to reach the value of 1.

2.5. The matrix of linkage mechanisms of NVAIS

Respondents, who decided that their component has a medium strength or strong linkages with the rest of other components in the system, were asked to determine mechanisms of these linkages. The linkage mechanisms of NVAIS, Matrix 4, show only the links established through a specific linkage mechanisms. The mechanisms matrix of NVAIS is a very weak matrix; Only 14 linkages are established through specific linkage mechanisms. The density of mechanisms matrix declines from 0.61 to 0.19.

$$\begin{bmatrix} P & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & O & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 1 & R & 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & S & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & H & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 & E & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 & 0 & F & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & M & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & C \end{bmatrix}$$

Matrix 4: The mechanisms matrix of NVAIS

The cause-effect values of the mechanisms matrix are remarked as follows: (0, 0) for P, (2, 2) for O, (3, 3) for R, (0, 0) for S, (2, 3) for H, (3, 0) for E, (3, 5) for F, and (0, 0) for C. The scattered plot of these cause-effect values presented in **Figure 3** show that the component R remains the most interactive, and is followed by O. The component F remains the subordinate component, and is followed by H. The components P, S and C moves downward. It is important to note that components F and R attract most attention from others, as manifested by the fact that it is the most interactive components within the system.

Findings listed in **Table 3** show linkages mechanisms in the NVAIS. These mechanisms include application of R&D projects, information sharing, problem diagnosis, technology diffusion & demonstration, workshops, seminars, personnel training, purchasing farm inputs, and marketing agricultural products.
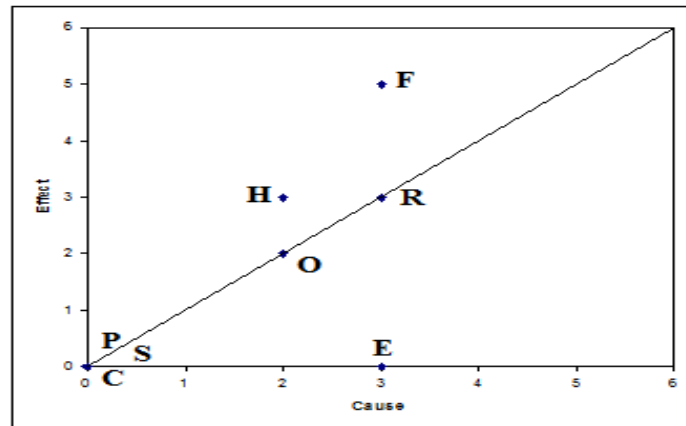

Figure 3. The *Cause-Effect* structure of NVAIS$_{[M]}$

Table 3. Mechanisms of linkages within the NVAIS

No.	Linkages	Mechanisms
1.	O→H	Problem diagnosis, demonstration
2.	O→F	Information sharing
3.	R→O	Conducting the R&D projects
4.	R→H	Conducting the R&D projects, information sharing, workshops, seminars
5.	R→F	Information sharing, problem diagnosis, technology diffusion & demonstration
6.	H→R	Conducting the R&D projects, information sharing
7.	H→F	Information sharing, problem diagnosis
8.	E→R	Information sharing
9.	E→H	Information sharing
10.	E→F	Technology diffusion, problem diagnosis
11.	F→O	Problem solving
12.	F→R	Problem diagnosis & solving
13.	F→M	Purchasing farm inputs, marketing agricultural products
14.	M→F	Purchasing farm inputs, marketing agricultural products

Source: the study findings

3. Assessment of information flow through the system

3.1. The information flow matrix of NVAIS

To evaluate how effectively information flows and to identify important receivers and senders of the information, linkages in the NVAIS matrix, **Matrix 2,** gives components capacities to receive (θ), learn (λ), and share (σ) information and resulted in the NVAIS matrix of information flow. Capacity of components to learn information is placed in the diagonal cells, and theirs capacities to share and receive are placed in off-diagonal cells of the information flow matrix of NVAIS. For example, capacity of the component P to receive information from other is donated by θ^P, its capacity to learn information is donated by λ^P and its capacity to share information with others is donated by σ^P. The function ($\sigma^P \theta^O$) in 1st raw 2nd columns refers to capacity of P to share information with O and receive information from it. While the structure ($\sigma^O \theta^P$) in 2nd row 1st columns refers to capacity of O to share information with P and receive information from it **(Matrix 5).**

$$
\begin{bmatrix}
P(\lambda^P) & \sigma^P\,\theta^O & \sigma^P\,\theta^R & \sigma^P\,\theta^S & \sigma^P\,\theta^H & \sigma^P\,\theta^E & \sigma^P\,\theta^F & 0 & \sigma^P\,\theta^C \\
\sigma^O\,\theta^P & O(\lambda^O) & \sigma^O\,\theta^R & 0 & \sigma^O\,\theta^H & \sigma^O\,\theta^E & \sigma^O\,\theta^F & 0 & \sigma^O\,\theta^C \\
\sigma^R\,\theta^P & \sigma^R\,\theta^O & R(\lambda^R) & 0 & \sigma^R\,\theta^H & \sigma^R\,\theta^E & \sigma^R\,\theta^F & 0 & 0 \\
\sigma^S\,\theta^P & 0 & 0 & S(\lambda^S) & 0 & 0 & \sigma^S\,\theta^F & 0 & 0 \\
\sigma^H\,\theta^P & \sigma^S\,\theta^O & \sigma^S\,\theta^R & 0 & H(\lambda^H) & \sigma^S\,\theta^E & \sigma^S\,\theta^F & 0 & 0 \\
\sigma^E\,\theta^P & \sigma^E\,\theta^O & \sigma^E\,\theta^R & 0 & \sigma^E\,\theta^H & E(\lambda^E) & \sigma^E\,\theta^F & 0 & \sigma^E\,\theta^C \\
\sigma^F\,\theta^P & \sigma^F\,\theta^O & \sigma^F\,\theta^R & 0 & 0 & \sigma^F\,\theta^E & F(\lambda^F) & \sigma^F\,\theta^M & 0 \\
\sigma^M\,\theta^P & \sigma^M\,\theta^O & 0 & 0 & 0 & \sigma^M\,\theta^E & \sigma^M\,\theta^F & M(\lambda^M) & 0 \\
\sigma^C\,\theta^P & \sigma^C\,\theta^O & 0 & 0 & 0 & \sigma^C\,\theta^E & \sigma^C\,\theta^F & 0 & C(\lambda^C)
\end{bmatrix}
$$

Matrix 5. The information flow matrix of NVAIS

Respondents were asked to assess the capacities of their organization to receive (θ), learn (λ), and share (σ) information to other organizations within the system. Table 4 gives distribution of these scores across components in the NVAIS. The four-level scale is also used for this purpose as: 0 for absence of capacity (denoted by n), 0.33 for a weak (denoted by w), 0.66 for medium (denoted by m) and 1 for strong capacity (denoted by s). Using the information in table 4, and linkages in Matrix 5, the capacity matrix of NVAIS **(Matrix 6)** is drawn.

Table 4. Average capacities to receive (θ), learn (λ), and share (σ) information in the system

Components	Capacity to receive: θ	Capacity to learn: λ	Capacity to share: σ
Policy (P)	*weak (w=0.33)*	*weak (w=0.33)*	*weak (w=0.33)*
General observatory (O)	*weak (w=0.33)*	*medium (m=0.66)*	*medium (m=0.66)*
Research (R)	*weak (m=0.33)*	*medium (m=0.66)*	*weak (w=0.33)*
Secondary Education (S)	*weak (w=0.33)*	*weak (w=0.33)*	*weak (w=0.33)*
Higher Education (H)	*weak (w=0.33)*	*medium (m=0.66)*	*medium (m=0.66)*
Extension (E)	*weak (w=0.33)*	*medium (m=0.66)*	*medium (m=0.66)*
Farmers and farmers' organizations (F)	*medium (w=0.33)*	*medium (m=0.66)*	*weak (w=0.33)*
Private input supply and marketing (M)	*medium (m=0.66)*	*strong (s=1)*	*medium (m=0.66)*
Agricultural credit (C)	*weak (w=0.33)*	*weak (w=0.33)*	*weak (w=0.33)*

Source: the study's findings

$$
\begin{bmatrix}
P(w) & ww & ww & ww & ww & ww & wm & 0 & ww \\
mw & O(m) & mw & 0 & mw & mw & mm & 0 & mw \\
ww & ww & R(m) & 0 & ww & ww & wm & 0 & 0 \\
ww & 0 & 0 & S(w) & 0 & 0 & wm & 0 & 0 \\
mw & mw & mw & 0 & H(m) & mw & mm & 0 & 0 \\
mw & mw & mw & 0 & mw & E(m) & mm & 0 & mw \\
ww & ww & ww & 0 & 0 & ww & F(m) & wm & 0 \\
mw & mw & 0 & 0 & 0 & mw & mm & M(s) & 0 \\
ww & ww & 0 & 0 & 0 & ww & wm & 0 & C(w)
\end{bmatrix}
$$

Matrix 6: The capacity matrix of NVAIS

3.2. The adjusted capacity matrix of NVAIS

By adjusting the capacity matrix of NVAIS, **Matrix 6,** linkages are converts to capacity parameters for effective information flow between components. In the conversion of the scores into the parameters the function $\sigma^P \theta^O$ which (1st row, 2nd column) indicates the information flow from P to O. From information flow matrix of NVAIS and table 4, function ($\sigma^P \theta^O$) = (*w, w*) = (0.33, 0.33), hence $\sigma^P \theta^O$ = 0.33*0.33 = 0.1, which is the capacity parameter corresponding to the flow of information from P to O. This parameter indicates how effective P is in transmitting information to O. by repeating the same action with all linkages, the following adjusted capacity matrix of NVAIS, **Matrix 7,** is resulted.

$$
\begin{bmatrix}
P(0.3) & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.2 & 0 & 0.1 \\
0.2 & O(0.7) & 0.2 & 0 & 0.2 & 0.2 & 0.4 & 0 & 0.2 \\
0.1 & 0.1 & R(0.7) & 0 & 0.1 & 0.1 & 0.2 & 0 & 0 \\
0.1 & 0 & 0 & S(0.3) & 0 & 0 & 0.2 & 0 & 0 \\
0.2 & 0.2 & 0.2 & 0 & H(0.7) & 0.2 & 0.4 & 0 & 0 \\
0.2 & 0.2 & 0.2 & 0 & 0.2 & E(0.7) & 0.4 & 0 & 0.2 \\
0.1 & 0.1 & 0.1 & 0 & 0 & 0.1 & F(0.7) & 0.2 & 0 \\
0.2 & 0.2 & 0 & 0 & 0 & 0.2 & 0.4 & M(1.0) & 0 \\
0.1 & 0.1 & 0 & 0 & 0 & 0.1 & 0.2 & 0 & C(0.3)
\end{bmatrix}
$$

Matrix 7: The adjusted capacity matrix of NVAIS

3.3. Effective Capacity-Weighted matrix of NVAIS

The Capacity-Weighted system is obtained by the product of each cell in the adjusted capacity matrix of NVAIS, **Matrix 7,** (except the diagonal cells) with the corresponding cell in refined linkages matrix of NVAIS, **Matrix 2.** These calculations resulted in the following effective capacity-weighted matrix of NVAIS, **Matrix 8.** This matrix represents an information flow structure, indicating how fluid the information in the system is.

$$
\begin{bmatrix}
P & 0.2 & 0.2 & 0.1 & 0.1 & 0.2 & 0.4 & 0 & 0.1 \\
0.4 & O & 0.6 & 0 & 0.4 & 0.2 & 1.2 & 0 & 0.2 \\
0.1 & 0.2 & R & 0 & 0.2 & 0.2 & 0.6 & 0 & 0 \\
0.1 & 0 & 0 & S & 0 & 0 & 0.2 & 0 & 0 \\
0.2 & 0.2 & 0.4 & 0 & H & 0.2 & 0.8 & 0 & 0 \\
0.2 & 0.2 & 0.4 & 0 & 0.4 & E & 1.2 & 0 & 0.2 \\
0.1 & 0.2 & 0.2 & 0 & 0 & 0.1 & F & 0.6 & 0 \\
0.2 & 0.2 & 0 & 0 & 0 & 0.2 & 0.8 & M & 0 \\
0.1 & 0.1 & 0 & 0 & 0 & 0.1 & 0.4 & 0 & C
\end{bmatrix}
$$

Matrix 8: The effective capacity-weighted matrix of NVAIS

3.4. The information flow structure in the NVAIS effective capacity-weighted matrix

The Supply is defined as the degree of the information supplements of a single component to each of the rest of the components; and the Receipt, as the Information reception of a single component from each of the rest of the components. These definitions imply that rows in the effective capacity-weighted matrix of NVAIS, **Matrix 8,** represent information supply while columns represent a receipt. For example, by the combination of the values in the 1st row in the **Matrix 8** indicates that the score of P as an information supplier is about 1.3; while the combination of values in the 1st column indicates that the score of component P as an information receiver is about 1.4. The supply-receipt values of the effective capacity-weighted matrix of NVAIS, Matrix 8, are: (1.3, 1.4) for P, (3.0, 1.3) for O, (1.3, 1.8) for R, (0.3, 0.1) for S, (1.8, 1.1) for H, (2.6, 1.2) for E, (1.2, 5.6) for F, (1.4, 0.6) for M, and (0.5, 0.7) for C. The scatter plot of these values resulted from the information flow structure, **Figure 4**. The component O is by far the main sender of information, followed by E and H (those components placed under the 45-degree line). The main receivers of information, on the other hand, is F. Components of R, P, and H have a special position in this system, being the most interactive components as it sends as much information as it receives from others.
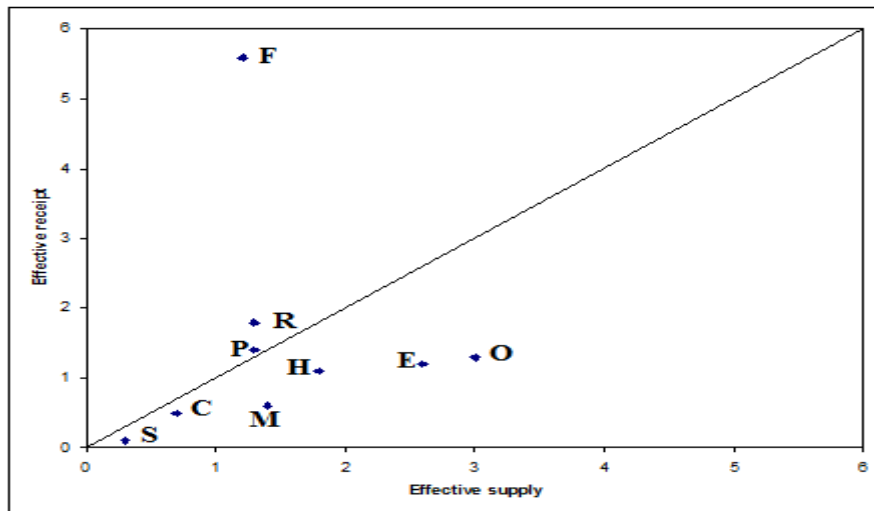
Figure 4. Information flow in the effective capacity-weighted matrix of NVAIS

CONCLUSIONS

This study seeks to map the existing agricultural innovation system in the New Valley governorate, Egypt, using a graph-theoretical technique. The primary objectives are to assess linkages and information flow in the system.

Decision makers can use the linkage matrix to assess alternative pathways, as it illustrates all the possible paths in the in the NVAIS; furthermore, the linkages have to be established (or strengthened) urgently; linkages of secondary importance; and the areas where no linkages (channels of information) are needed at the moment because the functions represented by these linkages could be established through pathways. The linkage matrix of the NVAIS also illustrates the effective pathways to the realization of specific goals. A pathway which starts and ends with the same component, feedback pathway, helps that component to assess its effectiveness.

Decision makers can use the linkage matrix to identify the constraints facing the NAAIS. Components S and C of the NVAIS interact other components at a low tone. This is reflected on the fact that they are candidates to reform. The component M is isolated component that needs to deal efforts on enhancing its interaction within other components of the system. The component O is a

dominant component, its effect on other components is much greater than others' influence on it. On the contrary, the component F is subordinate; it found to be the sink of influence since it is influenced by others more than it influences them. That means any of interventions on these two components will be reflected in all over the system. The intermediary institutions, O and E, should play a more active role in bringing together the components S, F, M, and C and P, R and H. Specifically, links between these components could be strengthened through policy dialogues where the O and E could pass information from S, F, M, and C to P, H and R. Such transmission of information should help P, R and H reassess agricultural policy, agricultural research priorities and agricultural education priorities, respectively.

The adjusted NVAIS [r] matrix represents a cause-effect structure, showing the influence of each component on others. Effective NVAIS [Capacity-Weighted] matrix, on the other hand, represents an information flow structure, indicating how fluid the information in the system is. These two structures provide complementary information to the design of innovation policy interventions.

To speed up information flow in the most efficient and effective way; the component O is qualified for that task and therefore, should be a potential target for policy interventions. Component E can also be targeted, occupy-

ing a comparable position both in **Figure 2** and **Figure 4.** Based on the information flow structure, **Figure 3,** strategies for collaboration in producing or buying information could be developed. Components O and E should collaborate in producing information, while components F, R and P should collaborate in buying information. The components, S, M, and C, however, seem to suffer from the lack of content, implied by the observation that only few components are able to produce information and that most organizations within the system rely on information received from others. Hence, a good strategy for them together is to collaborate in content creation efforts.

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