

**Systems Analysis by Graph Theoretical Techniques:
Assessment of the Agricultural Innovation System of
Azerbaijan**

Tugrul Temel

International Service for National Agricultural Research
P.O. Box 93375, 2509 AJ The Hague, The Netherlands
t.temel@cgiar.org

Willem Janssen

International Service for National Agricultural Research
P.O. Box 93375, 2509 AJ The Hague, The Netherlands
w.janssen@cgiar.org

Fuad Karimov

Agency for Support to the Development of the Agricultural Private Sector
U. Hajibekov Street 40, Government House Room No. 848
Baku 370016, Azerbaijan
karimovfuad@yahoo.com

Discussion Papers are preliminary reports of work in progress at the International Service for National Agricultural Research (ISNAR). They are intended to stimulate discussion and elicit comments from interested professionals both within and outside ISNAR. They are not official publications, they are not edited or reviewed by ISNAR, and their circulation is restricted. Discussion Papers reflect the views of the authors but not necessarily those of ISNAR. They may be cited with the authors' permission and due acknowledgment.

International Service for National Agricultural Research (ISNAR)
P.O. Box 93375
2509 AJ The Hague
The Netherlands
Tel: (31) 70-3496100
Fax: (31) 70-3819677
E-mail: isnar@cgiar.org
Internet: www.cgiar.org/isnar

ABSTRACT

This study introduces a graph-theoretic method for assessing linkages between components of a system and applies it to characterize the agricultural innovation system of Azerbaijan. The method promises wide applications among policy makers who are interested in assessing alternative innovation policies and/or programs by identifying effective pathways of interactions between the components and the constraints that hinder these interactions. Empirical findings suggest that there is ample scope for intermediary organizations to facilitate effective flow of knowledge between the public and the private components. But the development of such organizations calls for an enabling institutional environment. A second characteristic is that the growth of new links and/or the strengthening of the existing ones are constrained mainly by limited financial and human resources. Last but not least, the national research system should adopt a more proactive approach to collaborative research with international organizations. But this approach requires national research organizations to adopt flexible management styles.

Key words: Systems analysis, graph theory, agricultural innovation system, agricultural research policy, Azerbaijan.

JEL classification: Q2, C8

ACKNOWLEDGEMENTS

Special thanks go to Prof. John A. Hudson, who acquainted Tugrul Temel with the literature on the graph theory. Thanks also go to a large number of interviewees, Jalal Aliyev, Mamadzadeh Nabiyev, Asad Musayev, Irsad Aliyev, Eldar Kosayev, Ahmedov Vugar, Akberov Zeynal, and Mahmudov Rafail for their insights into the workings of the system. For their comments on the earlier version of the study, we further thank to Larry Zuidema, Ajit Maru, Kayo Narita, Thomas Braunschweig, Doug Horton, and seminar participants at ISNAR. Thanks also go to Astrid Oosterling for her excellent technical assistance. While acknowledging contributions from a wide variety of participants, we are responsible for the content of the study.

INTRODUCTION

Recent advancement of efficient computing algorithms and computational capacity of computers have spurred wide application of some concepts and techniques of graph theory in economics, political science, sociology, and psychology (Shrum, 1997; Richardson, 1999; OECD, 1997, 1999; Scott, 2000; among others). It has also become widely recognized that these techniques would serve as useful tools for characterizing hard and soft systems (Manescu, 1980; Murota, 1987; Cormen, Leiserson, and Rivest, 1990; Hudson, 1992).

Applications to date of the systems approach to analysis of organizational interactions remained at the conceptual level due mainly to the difficulty of formulating organizational objectives as optimization problems. In recent years, however, representation of systems as square matrices made it possible to bridge the gap between conceptual descriptions of systems and their quantitative characterizations. And the bridge was occupied with practitioners applying graph theoretical concepts, techniques, and results to study properties of systems. Freeman (1997, 2000), for example, utilized social network concepts to analyze underlying hierarchical properties of organizational structures, and in a similar fashion OECD (1997, 1999) studied common patterns across innovation systems of the selected OECD countries.

The present study introduces a graph theoretical method for characterizing organizational linkages in a system, defined as a set of organizations formally or informally organized around a common goal. The method is especially useful in evaluating questionnaires that concern organizational linkages, and requires the representation of these linkages in a square matrix. To illustrate the method, the paper applies it to the agricultural innovation system of Azerbaijan (AISA). More specifically, it measures the linkages between the components, identifies the dominant and subordinate components, illustrates by examples how to develop effective policies or programs, and discusses ways to improve the effectiveness of the system. Data required for the analysis were obtained from the questionnaire conducted by Temel, Janssen, and Karimov (2001).

Systems approach is useful for examining innovation systems because science is necessary but not sufficient for the generation, diffusion, and application of new technologies, and because learning takes place everywhere in society (EC, 2000). However, decision makers and policy analysts demand more practical and applied frameworks to predict consequences of their decisions and/or actions. With the method introduced in this study, they should be able to identify the existing cause-effect pathways, detect leverage points and mismatches, and develop alternative scenarios to release the constraints on innovative performance of the system concerned.

On the theoretical front, the linkage measurement would allow to study dynamics of agricultural knowledge generation, diffusion, and application and hence the role of agriculture in economic development. In addition, knowledge of the dominant and subordinate components is also an important piece of information necessary for the controllability of the system. And policy makers would greatly benefit from such information when designing policies or programs. Finally, knowledge of the sequencing of linkages would especially be valuable in constructing game theoretic models, as equilibria in these models are conditional to a specific sequencing of decisions made by participating agents.

A GRAPH-THEORETIC METHOD

This section introduces several graph theoretical concepts used in the analysis of the AISA.

Concept 1. A linkage matrix \mathbf{S} is defined as a matrix that maps cross-component linkages relating to a specific goal. Consider the AISA. The goal of this system is to develop, diffuse, and apply new or improved technologies. For illustrative purposes, suppose that the AISA consists of 5 components: Policy (P), Research (R), Information (I), Farm organization (F), and External assistance (X). The components are placed in the diagonal cells, and following clock-wise convention, their linkages are placed in the off-diagonal cells of \mathbf{S} .

$$\mathbf{S} = \begin{bmatrix} P & PR & PI & PF & PX \\ RP & R & RI & RF & RX \\ IP & IR & I & IF & IX \\ FP & FR & FI & F & FX \\ XP & XR & XI & XF & X \end{bmatrix}.$$

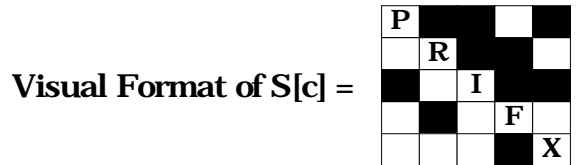
The term PR in the 1st row – 2nd column of \mathbf{S} represents the linkage that representatives of organizations under Component P commonly claim to have had with those organizations under Component R. Likewise, the term RP in the 2nd row – 1st column of \mathbf{S} represents the linkage that representatives of organizations under Component R commonly claim to have had with those organizations under Component P. The terms placed in the off-diagonal cells of \mathbf{S} represent binary (or one-edge or one-to-one) linkages, meaning that the two components are linked with no intermediary linkages, like P→R. A linkage between P and R can also be established through a pathway, like P→I→F→R, which is called a three-edge pathway of linkages. The maximum number of edges is equal to $(n-1)=4$, where n denotes the number of components in \mathbf{S} .

Organizational linkages can be characterized in terms of information, knowledge, and resource (physical and monetary) flows. These are of three types. The first is the linkages as claimed by individuals interviewed; the second, the linkages as expected by the individuals interviewed; and the third, the linkages actually realized. Surveys, structured individual interviews, and stakeholder workshops are among the tools to identify claimed and expected the linkages. For the identification of realized linkages, organizational activities should be classified by linkage mechanisms (such as meetings, correspondence, commissions, etc.), the flows (such as of information, knowledge, and resources) in which these mechanisms are employed, and frequency of use of the mechanisms. The frequency may indicate the intensity and strength of the linkages. Mapping of all the linkages should allow us to identify areas where expectations are not fulfilled and areas where there is a gap between claimed and realized linkages.

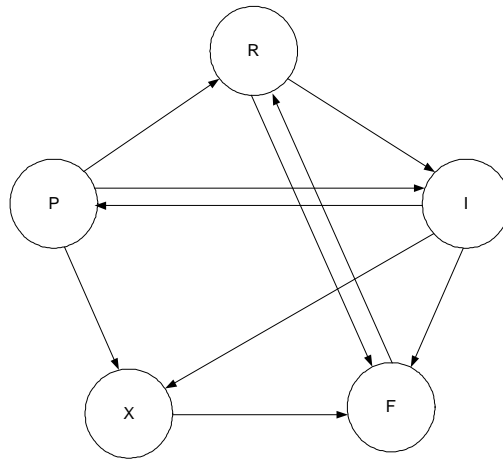
Concept 2. A coded linkage matrix $\mathbf{S}[c]$ is defined as a matrix with binary codes: 0 for absent and 1 for existing linkages. For illustrative purposes, we construct an arbitrary matrix $\mathbf{S}[c]$,

$$S[c] = \begin{bmatrix} P & 1 & 1 & 0 & 1 \\ 0 & R & 1 & 1 & 0 \\ 1 & 0 & I & 1 & 1 \\ 0 & 1 & 0 & F & 0 \\ 0 & 0 & 0 & 1 & X \end{bmatrix}$$

where the component P has a linkage with R, I, and X, and the component R expresses a linkage with I and F but not with P etc. It should be noted that PR exists but RP does not, which is manifested by 1 in the 1st row – 2nd column and 0 in the 2nd row – 1st column of S[c], respectively. This coding offers a way of representing something that is claimed to exist, and therefore, S[c] is not necessarily symmetric. Below, S[c] is shown in a different format to detect visual patterns, where black (white) cells indicate the existing (nonexistent) links:



A third format to represent S[c] is to define it as a *digraph* (i.e., *directed graph*). The digraph consists of five vertices, P, R, I, F, X, and assumes an implicit function that translates the linkages into real values {0, 1}. Although it is difficult to recognize patterns immediately in the following diagram, this format has its own advantages.



Concept 3. The matrix S[c] can be refined using the questionnaire in Appendix. Individuals interviewed by using the questionnaire would provide opinions on the degree of linkages their organizations have developed with the rest of the organizations in the system. Since the answers to the questions are all expressed in scales, like none, weak, medium, and strong, we can assign to each scale a value: 0 for a nonexistent, 1 for a weak, 2 for a medium, and 3 for a strong linkage.¹ This procedure would yield a vector of values representing the degree of linkages between the interviewed organization and the rest of the organizations in the system. Repeating the same procedure for each organization would result in as many vectors as organizations. Next, the components are defined as subsets of the organizations already

¹ Note that if the scale consists of such categories as “very harmful”, “harmful”, “neutral”, “useful”, and “very useful”, then an appropriate set of values to be assigned to these categories would be -2, -1, 0, 1, and 2, respectively. For more reading on measurement techniques for surveys with scaled questions, the reader is referred to Miller (1956) and Tull and Hwakins (1984).

characterized and the vector of values assigned to the organizations in each subset is reduced to an average vector by averaging over the relevant values. By averaging, we aim to reduce the dimensions of the system at hand from the number of organizations to the number of components. Suppose that repeating this procedure for each component yields the refined system $S[r]$,

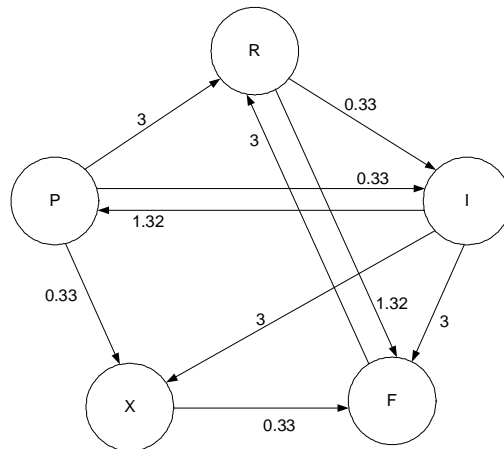
$$S[r] = \begin{bmatrix} P & 3 & 1 & 0 & 1 \\ 0 & R & 1 & 2 & 0 \\ 2 & 0 & I & 3 & 3 \\ 0 & 3 & 0 & F & 0 \\ 0 & 0 & 0 & 1 & X \end{bmatrix}.$$

The values in $S[r]$ represent the degree of binary linkages claimed only and that these linkages, by definition, do not imply direction of influence.

Concept 4. By adjusting $S[r]$, we transform the linkages to the influences between components. During the interview, questions are asked to determine how strongly the interviewed organization believes to influence the others in the system. Depending on the degree of claimed influence, which is scaled as none ($n=0$), weak ($w=0.33$), medium ($m=0.66$), and strong ($s=1$), $S[r]$ is adjusted as:

$$\text{Adjusted } S[r] = \begin{bmatrix} P & 3.s & 1.w & 0.n & 1.w \\ 0.n & R & 1.w & 2.m & 0.n \\ 2.m & 0.n & I & 3.s & 3.s \\ 0.n & 3.s & 0.n & F & 0.n \\ 0.n & 0.n & 0.n & 1.w & X \end{bmatrix} = \begin{bmatrix} P & 3 & 0.33 & 0 & 0.33 \\ 0 & R & 0.33 & 1.32 & 0 \\ 1.32 & 0 & I & 3 & 3 \\ 0 & 3 & 0 & F & 0 \\ 0 & 0 & 0 & 0.33 & X \end{bmatrix}.$$

Concept 5. The cause-effect structure of Adjusted $S[r]$ is established as follows. Cause (C) is defined as the influence of a single component on each of the rest of the components in Adjusted $S[r]$; and Effect (E), as the influence of each of the rest of the components on that single component. These definitions, together with the clock-wise convention that was followed in the construction of the matrix S , imply that rows (columns) in Adjusted $S[r]$ represent cause (effect). For example, the 2nd row indicates R's influence on P, I, F, and X, while the 2nd column indicates others' influence on R. The binary influences in Adjusted $S[r]$ can also be represented as a directed graph:



With a value of 3, the arrow from P to R indicates P's influence on R. Similarly, with a value of 1.32, the arrow from R to F indicates R's influence on F. Hence, the total cause of P on the rest of the system is 3.66, which is the sum of the values in the 1st row of Adjusted $\mathbf{S}[\mathbf{r}]$, and the total effect of other components on P is 1.32, which is the sum of the values in the 1st column of Adjusted $\mathbf{S}[\mathbf{r}]$. The C-E coordinates are then (3.66, 1.32) for P, (1.65, 6) for R, (7.32, 0.66) for I, (3, 4.65) for F, and (0.33, 3.33) for X. The scatter plot of these coordinates in Figure 1 helps identify dominant and subordinate components. The component I is dominant, implied by the observation that it influences the system much more than others' influence on it. On the contrary, the component R is subordinate, implied by the observation that others influence it much more than its influences on others.

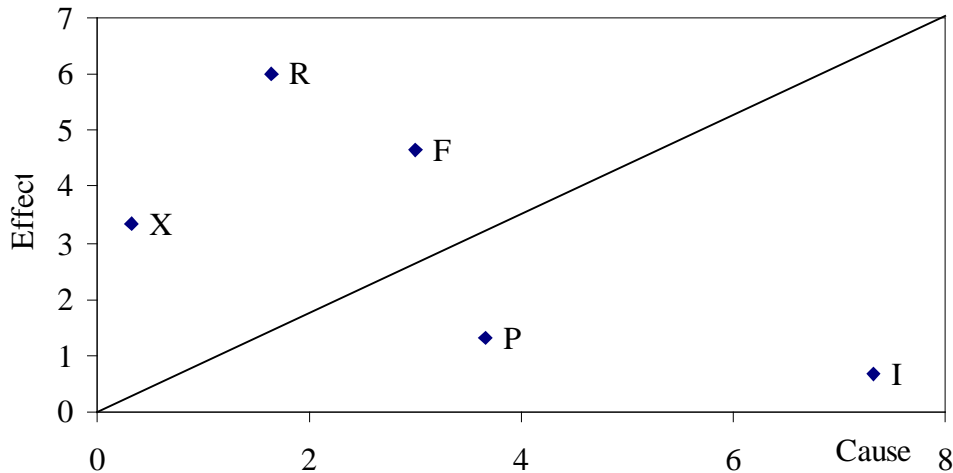


Figure 1. The cause-effect structure of Adjusted $\mathbf{S}[\mathbf{r}]$

Concept 6. The density of Adjusted $\mathbf{S}[\mathbf{r}]$, 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 influences, and n is the number of dimensions of Adjusted $\mathbf{S}[\mathbf{r}]$. Thus, $\mathbf{S}[\mathbf{r}]$ has a density of 0.5, where $b=10$ and $n=5$. A structure is said to be fully identify if $d=1$, which implies that all the components positively influence each other.

Concept 7. A cluster is a subset of components concentrated around a (C, E)-coordinate. The C-E structure is a useful tool for visually detecting clusters in the system. This concept, useful especially in a system with a large number of components, helps identify subsystems and examine their characteristics.

AN APPLICATION

Definitions

The literature introduces various definitions of national innovation system. Freeman (1987), for example, defines it as a network of institutions in the public and private sectors whose activities and interactions initiate, import, modify, and diffuse new technologies. Nelson (1993) describes it as a set of institutions whose interactions determine the innovative performance of productive units. Metcalfe (1995) and Smith et al. (1996) consider it as set of distinct institutions that jointly and individually contribute to the development, diffusion, and application of new technologies. While these definitions are quite similar at face value, there are some differences in meaning, emphasis, and use of the concept. The key difference is that

some view the concept as a simple aggregation of organizations, while others point at the synergies that originate from their joint operation.

This study's point of departure is that the innovation system is not a simple aggregation of organizations, but it is a group of organizations that operate like an *invisible orchestra*, each member of which plays pieces of a one-big melody. This orchestra is characterized by coherence, harmony, and synergy: coherence brings different pieces under the same melody, harmony creates a tune that keeps the members around the same spirit; and synergy ties them more strongly around the common goal. The study defines agricultural innovation system as a set of organizations (including farm organizations, input supply-processing-marketing enterprises, research and education institutions, credit institutions, extension and information units, consultancy firms, international development organizations and donors, and the government) that jointly and/or individually contribute to the development, diffusion, and use of new agriculture-related technologies, and that directly and/or indirectly influence the process of technological change in agriculture.

Data

Data were gathered using the questionnaire in Appendix.² The questionnaire has two distinct features. The first is that organizational linkages are scaled as 0 for absent, 1 for weak, 2 for medium, and 3 for strong linkage. This scaling shows only how strongly a linkage mechanism was used during the interaction of two organizations. This information helps us construct $S[r]$. The second feature is that during the interview channels through which the interviewed organization influenced the others in the system were discussed. And this information was used to determine Adjusted $S[r]$.

| <u>Components</u> | <u>Number of persons interviewed</u> |
|-------------------------------------|--------------------------------------|
| Policy | 7 |
| Research | 12 |
| Education | 5 |
| Credit | 1 |
| Extension and information | 4 |
| Inputs-processing-outputs marketing | 8 |
| Farm organizations | 10 |
| Private consultancy | 11 |
| External assistance | 5 |
| Total | 63 |

Components of the AISA

It should be stated from the outset that this section draws on the findings documented in Temel, Janssen, and Karimov (2001). The organizational structure of the AISA illustrated in Figure 2 also draws on the same study. The only thing adopted from OECD (1999) is the format of Figure 2, not the content.

² This questionnaire is only a small portion of a much broader questionnaire that was carried out in Azerbaijan. For the full version of the questionnaire, the reader is referred to Temel, Janssen, and Karimov (2001). Directors and/or managers of organizations within each component have been chosen in consultations with the director of Agrarian Science Center of Azerbaijan.

In Figure 2, organizational links and functions are classified in 6 categories: general policy-making (F1), policy formulation, co-ordination, supervision and assessment (F2), financing R&D (F3), R&D performance (F4), technology diffusion (F5), and technology application (F6). The structure has 5 layers, each of which includes organizations performing one or two of the 6 functions. For example, the organizations in the 1st layer perform F1 and F3, those in the 2nd layer perform F2 and F3, etc. Below, the 9 components of the AISA are defined as subsets of these organizations.

Policy Component (P) comprises 5 key units operating under the responsibility of the Cabinet of Ministers: the State Committee for Science and Technology (SCST), the Ministry of Agriculture (MoA), the Ministry of Education (MoEd), the Ministry of Finance (MoF), and the Ministry of Economic Development (MoED). In addition, each unit has several commissions performing specific tasks to support the formulation of agricultural policy in general, and agricultural research policy in particular. Presently, the SCST is at a standstill due to the absence of science and technology priorities at the national level. The MoA and MoEd are also undergoing major changes concerning the organization and management of agricultural research, education, and information.

Research Component (R) consists of a total of 26 research institutes, 15 of which are under the Agrarian Science Center of Azerbaijan (ASCA) in the MoA and 11 operate under several committees and the Academy of Sciences (AS). Of these 11 institutes, 6 belong to the Academy of Sciences, 3 to the Committee for Water Economy, one to the Committee for State Land, and one to the “Azerforest” industrial amalgamation. In early 2000, the Agricultural Research Board (ARB) was created to coordinate the Competitive Grants System (CGS) for funding research projects.

The research component needs just about everything. It needs a mandate, research priorities, qualified personnel, funds, and access to knowledge and information on new technologies. Furthermore, this component is overly divided into separate bodies, making it very difficult to manage and coordinate the institutes. For survival purposes, experts in the experimental stations have now and then developed relations with international organizations via joint projects.

Education Component (E) comprises 42 universities (25 public, 17 private) and 77 colleges (73 public, 4 private), all of which are under the partial supervision of MoEd. Soon, the MoEd is expected to assume full responsibility for all educational institutions, including 21 agricultural colleges and one Agricultural Academy that used to be under the control of the MoA (ARKTN, 2000). The Agricultural Academy should, according to its mandate, engage in both teaching and research (mostly theoretical). The colleges, on the other hand, should engage in both teaching and applied research. The MoA will still be expected to supervise post-graduate education through the Head Dept. Scientific Research, Education, and Personnel Training (HDSREPT). Every year, a total of 8-10 post-graduate students are accepted to the 15 research institutes of the ASCA. Moreover, there are several agriculture-related faculties in Azerbaijan State University and other engineering and technical universities. Newly established in 2001 is the Agricultural Education Department in the MoEd. This Department is responsible for administrative coordination and curriculum preparation of the agricultural education institutions.

Constraints faced by education institutions are abundant. At the ministerial level, linkages are not well defined creating organizational communication problems between the MoEd and the MoA. Unclear roles and tasks at the departmental level slow down daily operations. Limited qualified personnel, low degree of expert mobility between related departments, lack of

appropriate sources of finance, and inadequate access to information are among the key problems encountered today. The education component is adversely influenced by an unclear agricultural education policy and the lack of educational priorities.

Credit Component (C) is going through substantial changes. By the end of 1999, the banking system comprised 70 banks, down from 180 in 1995. Four state-owned banks dominated the system, basically extending loans to public enterprises. For the last two years, no credit was provided to the agricultural sector. The 66 private banks also remained in a precarious state (Owen et al. 2000; ARKTN, 2000). At present, preparations are underway to merge the Agro-Industry and Security banks to create a Universal Bank. Most recently, the government of Azerbaijan has established an oil fund to help mobilize resources to rural sector in general, and to the agricultural sector in particular.

Extension and Information Component (I) comprises various centers and departments. The Information and Consulting Services Center (ICSC) was established in 2000 within the Agricultural Development and Credit Project (ADCP). Its task is to coordinate information and extension services specified in the ADCP, and its main activities are carried out at its regional branches. These branches provide extension services to people with land but without farming skills and to those without knowledge of how to prepare business plans or apply for credits or loans. Another activity of the Center, again through its branches, is to disseminate research results of projects implemented within the context of the competitive grants program. The Information Dissemination Unit (IDU) of the MoA was established in 1998 to coordinate agricultural knowledge flow at the national level. The IDU supports the introduction of new techniques or methods for information gathering about the current status of farming activities, provides extension services to farmers, and disseminates information about the new techniques available. Private enterprises also provide services in the information and extension sector, promoted indirectly by the ADCP and the FPP activities.

International organizations, private consultancies, farmers, and several research institutes are the major actors in this component. Typically, they use linkage mechanisms such as planning and review, technology diffusion, exchange of personnel, and sharing of information. The IDU of the MoA, private seed-marketing firms, and large farms are also in close contact, involving in joint problem diagnosis, program planning and review, and joint resource use. International organizations and private enterprises are the dynamic units of this component; however, cooperation between them is weak.

Private Enterprise Component (M) includes private input and output supply, processing, and marketing firms. A typical firm engages in all of these activities. Around 20 input supply firms currently operate in the market. Some have grown out of the pre-independence co-operatives, and some others have been established recently. With a total of 1759 agricultural processing enterprises, which are presently under the subordination of the Ministry of Economic Development, the processing sector is expected to have a large-scale privatization. A relatively speedy privatization has taken place in the cotton sector. All of the 19 cotton-processing plants are in private hands.³

Five trends emerge in this component. First, private input supply firms gradually make themselves known, specializing largely on the supply of seeds and plant protection materials. Second, large farms operate as producers, processors, and middleman. Third, monopolistic cotton companies engage in the complete chain of production. The chain starts from contractual arrangements with farmers. Inputs are provided to farmers, rarely public irrigation

³ The reader is referred to ARKTN (2000) for a more detailed information.

channels rehabilitated, raw cotton harvested and processed and then sold in the world market. Fourth, international companies are transmitters of new seed varieties (grains, vegetables, cotton) and of chemicals, pesticides, and herbicides. Finally, these firms also engage in extension services such as field demonstrations of input use.

The linkages of these private firms with other entities depend on the process in which the firms grew and on the type of product they are interested in. For example, the firms that grew out of the pre-independence co-operatives continue to have relations with research institutes of the MoA. Their only new relation is with international input supply companies. In this connection, these firms have developed “intimate” relations with the Seed Quality Control Unit of the MoA. These firms are in close relation with research institutes, the Quality control Unit, international seed supply firms, and farmers. They engage in joint problem diagnosis with experts from the research institutes, field demonstrations and training sessions with local customers, and the preparation of TV programs and of information booklets for farmers.

Private Farm Component (F) includes 6 types of farms: household farms, farmers’ holdings, collective enterprises, leased enterprises, production cooperatives, and small enterprises. Large farms could play a considerable role in the diffusion of new technologies since they undertake production, processing, and marketing activities simultaneously. They benefit from their structural suitability to the irrigation infrastructure and relatively easy access to other farm inputs on the one hand, and their close connections with experimental stations of research institutes on the other. Small farms, on the other hand, literally lack everything, but most important of all, they lack land large enough to think about agriculture for markets. They also lack the knowledge and skills required for market-oriented farm production.

Large and small farms paint an opposite picture regarding their linkages. A majority of farms privatised in 1993 were large since they were the first wave to break away from the old kolхозes. The managers of these kolхозes often bought the farms that they were operating for years. Naturally, their pre-existing ties were kept alive with the policy, research and education, input supply, processing, and marketing components. Rarely through project implementation, large farms have developed relations with international organizations that offer new seed varieties and new farming techniques. With them, these farms are involved in joint program development, problem diagnosis, technology demonstration, training, and information sharing. Small farms are, however, a simple expansion of garden plots, and thus, their relations are often with large farm operators. The existing regional farm associations are first not active, and second, they are likely to address the needs of large farms, if they active at all because the associations are usually run by large farm operators who maintain their old relations with policy makers.

Private Consultancy Component (D) emerged in 1998, with the law allowing for private consultancy firms. Since then, around 35 consultancy firms were founded. Many of them employ academicians, researchers, and post-graduate students. Their activities grow through opportunities offered by international development organizations and donors, and they are mostly active in areas relating to agriculture, ecology, and agro-business issues. In many cases these firms are spin-off entities growing around the “Information and Consulting Services” of the ADCP. The consultancy firms aim to provide all kinds of services to farmers, ranging from preparing business plans to problem diagnosis.

Several trends emerge in this component. First, the majority has already developed project-based relations with international development agencies and donors. Second, the majority has one foot in the private and the other in the public sector. Third, joint activities are not engaged

in with public organizations, although for some it is unavoidable to develop such relations, as their unit of investigation is the environment. Fourth, they are all relatively new, and therefore, are in the process of formulating their objectives and activities.

External Assistance Component (X) includes a variety of international development organizations, donors, and NGOs, and has been the key entry point for new or improved knowledge, processes, and practices. The international organizations expose the country to new knowledge and processes; however, the incomplete and weak legal framework hinders their performance. Joint project-based activities are the means for exposing national entities to international standards. These activities usually involve private consultancy firms, as they have relatively better human and physical resources and have flexible organizational structures. Public entities, however, have been slow in adapting to international standards due to organizational rigidities, continuing organizational changes, and lack of qualified personnel.

Three types of linkages evolve between international organizations and the rest of the system. First, formal relations are developed with policy units in order to legitimize goals of the projects undertaken by these organizations. Second, direct interactions are developed with beneficiaries of the projects. Close contacts are developed with farmers through training programs for promoting new farming techniques and agri-business practices. Third, formal and informal relations are growing with private market participants.

Mapping cross-component linkages

Table 1 (henceforth Linkage Matrix) maps the structure of cause-effect linkages between the 9 components. This structure is characterized by information gathered by the questionnaire in Appendix: (i) three types of linkages as formal (*f*), informal (*i*), and mixed (*m*), (ii) four levels of linkage strength as strong (*s*), medium (*m*), weak (*w*), and none (*n*), and (iii) five groups of linkage mechanisms. Also gathered during the interviews is information on the extent of an organization's influence on the others. The direction of influence between the components follows clockwise rotation. The 1st row of this matrix provides the information obtained from managers of the organizations under the component P. It shows the mechanisms and the ways by which these organizations claimed to influence the rest of the system. Likewise, the information placed in the 2nd row indicates how R claimed to influence the rest of the system. In a similar fashion, information placed in the 1st column of Linkage Matrix indicates mechanisms others in the system claimed to use to influence P. The same interpretations apply to other rows and columns in Linkage Matrix.

The matrix **S** below is a more compact representation of Linkage Matrix, where (*fw*) stands for a formal-weak, (*fm*) a formal-medium, (*fs*) a formal-strong, (*iw*) an informal-weak, (*im*) an informal-medium, (*is*) an informal-strong, (*mw*) a mixed-weak, (*mm*) a mixed-medium, and (*ms*) a mixed-strong relation. Zeros that appear in some of the off-diagonal cells imply either that linkage does not exist between the relevant components or that it exists at a negligible level, or that it exists but the investigator was not able to identify it.

$$\mathbf{S}^4 = \begin{bmatrix} \text{P} & fw & fw & fw & mw & 0 & 0 & 0 & fm^1 \\ fw & \text{R} & fw & 0 & mw & mm & im & im^1 & fw^1 \\ fw & fw & \text{E} & 0 & 0 & 0 & iw & im & fw^1 \\ fw & 0 & 0 & \text{C} & 0 & 0 & 0 & 0 & fw \\ fm^1 & fm^1 & 0 & 0 & \text{I} & 0 & fm^1 & fm^1 & fw^1 \\ fm & im & 0 & 0 & 0 & \text{M} & mm^1 & 0 & mw^1 \\ im^1 & im^1 & iw^1 & 0 & 0 & mw^1 & \text{F} & 0 & 0 \\ im^1 & im^1 & mm^1 & 0 & fm^1 & iw & mm^1 & \text{D} & fm^1 \\ fm^1 & fw & 0 & 0 & fs^1 & mw & fm^1 & fm^1 & \text{X} \end{bmatrix}$$

S has several distinct features. First, it shows that the AISA is not fully identified. Of a total of 72 relations, only 45 are identified. The AIS has a density of 0.63 (= 45/72) and the component C is almost fully isolated from the rest of the system. Second, it shows that the AIS is fairly flexible. Of 45 relations, 25 are formal (13 weak, 11 medium, 1 strong), 11 informal (3 weak, 8 medium, 0 strong), 9 mixed (5 weak, 4 medium, 0 strong). Third, all relations are formal and weak (*fw*) between the public components (P, R, E, C), while relations are mixed and mostly medium between the private components (I, M, F, D). This suggests a much stronger connection between the private components than that between the public sector components. Fourth, not surprisingly, informal relations are common between the public and the private components, reflected especially by the dominantly informal relations between (R, E) and (I, M, F, D). Equivalently important in this respect is the willingness of (M, F, D) to develop contacts with P, which is implied by (*fm*, *im*, *im*) in the first column and (0, 0, 0) in the first row. Lastly, the component X has one way or another developed relations with all the components in the system. The strongest relations are with I, F, D, and P.

Adjusted S and its cause-effect structure

Adjusted **S** below was constructed by assigning 0 for no influence, 1 for weak, 2 for medium, and 3 for strong influence in **S**. Figure 3 shows the cause-effect structure associated with Adjusted **S**, which has a density of 0.63. According to this structure, the component D dominates over the AISA, as it has more influence on the rest of the components than that others have on it. Interestingly, however, the component R and X are highly interactive⁵ with the rest of the system, and is followed by I, M, and E. Furthermore, the component P and F are found to be subordinate, as they are influenced by others more than they influence them. Lastly, the component C has almost no interaction with the rest of the system.

⁴ The links with a superscript 1 in **S** represent those established through specific linkage mechanisms. These are the links to which a value 1 is assigned to create **S**[m].

⁵ Points on the 45-degree line in Figure 3 indicate that components on this line are interactive with the rest of the system.

$$\text{Adjusted } \mathbf{S} = \begin{bmatrix} \text{P} & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 2 \\ 1 & \text{R} & 1 & 0 & 1 & 2 & 2 & 2 & 1 \\ 1 & 1 & \text{E} & 0 & 0 & 0 & 1 & 2 & 1 \\ 1 & 0 & 0 & \text{C} & 0 & 0 & 0 & 0 & 1 \\ 2 & 2 & 0 & 0 & \text{I} & 0 & 2 & 2 & 1 \\ 2 & 2 & 0 & 0 & 0 & \text{M} & 2 & 0 & 1 \\ 2 & 2 & 1 & 0 & 0 & 1 & \text{F} & 0 & 0 \\ 2 & 2 & 2 & 0 & 2 & 1 & 2 & \text{D} & 2 \\ 2 & 1 & 0 & 0 & 3 & 1 & 2 & 2 & \text{X} \end{bmatrix}$$

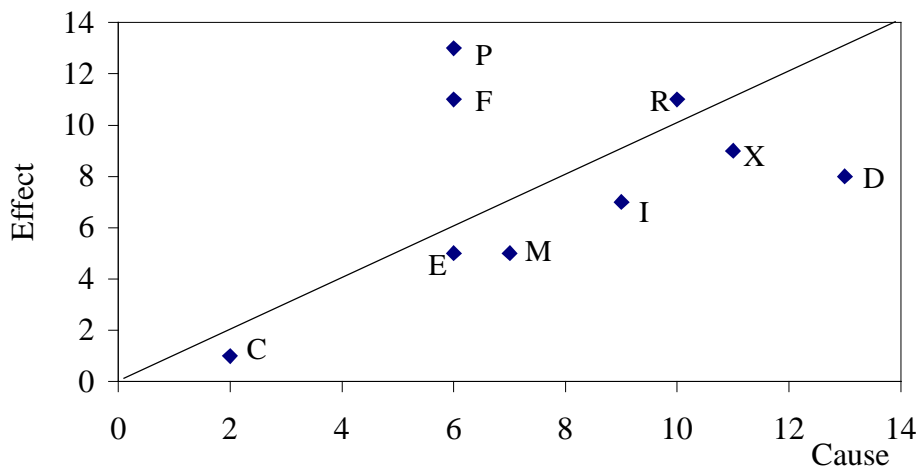
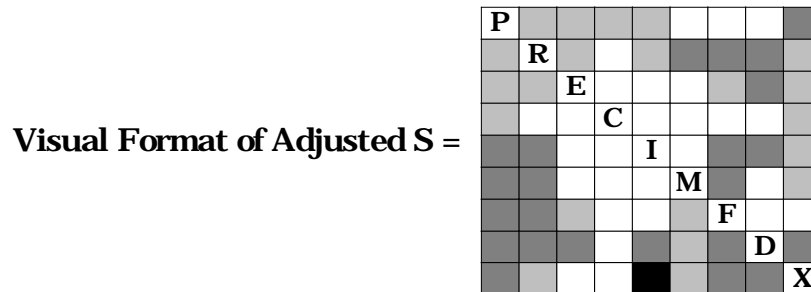


Figure 3. The cause-effect structure of **Adjusted S**

Presented below is a visual representation of the information in **Adjusted S**, where white cells represent no influence, grey cells weak influence, black cells medium influence, and heavily dark cells strong influence.⁶ The visual tool helps to detect areas to be strengthened for facilitating an effective and efficient flow of knowledge, while the cause-effect structure would indicate the components that can serve as the sources and sinks of this knowledge.



The system structure based on linkage mechanisms used

⁶ It is straightforward to develop computer algorithms to generate cause-effect structures and visual representations automatically. Such automation will be very helpful especially for studying large systems.

S[m] below, which has a density of 0.35, shows only those linkages established through specific mechanisms listed in Appendix. Figure 4 suggests polarization with respect to the use of these mechanisms between the private (D, I, F, X) and public (P, E, R) sectors. The component D remains to be the dominant one, which is followed by I. The component F is most interactive, which is followed by R and E. On the other hand, P remains to be the most subordinate. A visual examination of S[m] also clearly shows that D and X often carry out activities through linkage mechanisms. This can in part be attributed to the fact that their activities are strictly determined by formal rules and agreements.

$$S[m] = \begin{bmatrix} P & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & R & 0 & 0 & 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & E & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & C & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & I & 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & M & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 & 1 & F & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 & 0 & 1 & D & 1 \\ 1 & 0 & 0 & 0 & 1 & 0 & 1 & 1 & X \end{bmatrix}$$

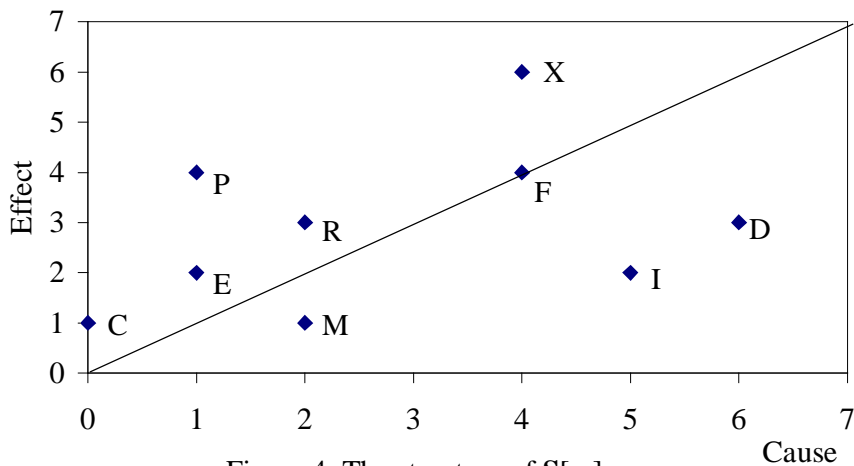
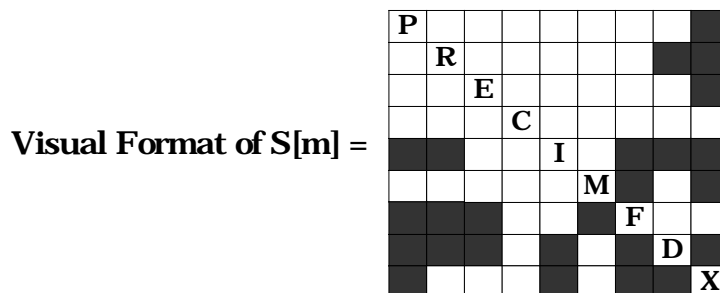


Figure 4. The structure of S[m]



WHO, WHEN, AND HOW TO USE THE METHOD

Decision makers can use the Linkage Matrix *to assess alternative pathways*, as it illustrates all the possible paths in the AISA. Consider, for example, a feedback pathway $P \rightarrow C \rightarrow I \rightarrow F \rightarrow R \rightarrow P$ in which initial change takes place in P and its influence is carried back to P through the pathway $C \rightarrow I \rightarrow F \rightarrow R$. Suppose that P introduces a rural development fund for farmers to have access to new technologies ($P \rightarrow C$). Executing actual transfer of funds, agricultural banks would disseminate information on procedures for loan or credit applications ($C \rightarrow I$). Extension agents, information dissemination workers, private consultants, etc. will all be busy with passing this information onto farmers ($I \rightarrow F$). The outcome of this process would be either by farmers' organization or by experts in regional information centers or by field researchers passed to regional extension units of research institutes ($F \rightarrow R$). Finally, success or failure of the initiative could be reported in a policy dialogue ($R \rightarrow P$). Once this cycle of cause and effect is completed, the government might be in a position to assess the effectiveness of its initiative. Under the current circumstances, this feedback pathway cannot be operational in Azerbaijan because necessary credit institutions are still absent.

Decision makers can use the Linkage Matrix *to identify effective pathways* to the realization of specific goals. The distribution to farms of new crop varieties is one such goal. Clearly, farmers F will be the end users of these varieties, but agents who pursue this goal might be diverse. External assistance organizations X, only one type of distributors in the AISA, would imply the set of pathways including $\{X \rightarrow F\}$, $\{X \rightarrow D \rightarrow F\}$, $\{X \rightarrow M \rightarrow F\}$, $\{X \rightarrow I \rightarrow F\}$, $\{X \rightarrow R \rightarrow F\}$, $\{X \rightarrow D \rightarrow M \rightarrow F\}$, $\{X \rightarrow D \rightarrow I \rightarrow F\}$, $\{X \rightarrow D \rightarrow R \rightarrow F\}$, $\{X \rightarrow I \rightarrow D \rightarrow F\}$, $\{X \rightarrow I \rightarrow R \rightarrow F\}$, $\{X \rightarrow R \rightarrow M \rightarrow F\}$, $\{X \rightarrow M \rightarrow R \rightarrow F\}$, $\{X \rightarrow R \rightarrow I \rightarrow F\}$, $\{X \rightarrow R \rightarrow D \rightarrow F\}$, $\{X \rightarrow R \rightarrow I \rightarrow D \rightarrow F\}$, $\{X \rightarrow R \rightarrow D \rightarrow I \rightarrow F\}$, $\{X \rightarrow R \rightarrow D \rightarrow M \rightarrow F\}$, $\{X \rightarrow R \rightarrow I \rightarrow D \rightarrow M \rightarrow F\}$, and $\{X \rightarrow M \rightarrow R \rightarrow I \rightarrow D \rightarrow F\}$. The fact that farmers in Azerbaijan operate with very limited budget and that they are strongly risk averse reduces this set to $\{X \rightarrow M \rightarrow F\}$, $\{X \rightarrow R \rightarrow F\}$, $\{X \rightarrow R \rightarrow M \rightarrow F\}$, $\{X \rightarrow M \rightarrow R \rightarrow F\}$, $\{X \rightarrow R \rightarrow I \rightarrow F\}$, $\{X \rightarrow R \rightarrow D \rightarrow F\}$, $\{X \rightarrow R \rightarrow I \rightarrow D \rightarrow F\}$, $\{X \rightarrow R \rightarrow D \rightarrow I \rightarrow F\}$, $\{X \rightarrow R \rightarrow D \rightarrow M \rightarrow F\}$, $\{X \rightarrow R \rightarrow I \rightarrow D \rightarrow M \rightarrow F\}$, and $\{X \rightarrow M \rightarrow R \rightarrow I \rightarrow D \rightarrow F\}$. The rationale behind it is that either profit maximizing input-output supply firms, represented by M, or social welfare-maximizing public institutes, represented by R, would involve in the process by providing farmers with information, inputs, and technical support. Under the current circumstances, the set of feasible pathways would include only $\{X \rightarrow M \rightarrow F\}$, $\{X \rightarrow M \rightarrow R \rightarrow F\}$, and $\{X \rightarrow M \rightarrow R \rightarrow I \rightarrow D \rightarrow F\}$ because social benefits of switching from subsistence to market-oriented farming outweigh private benefits. The most effective pathway, which is the shortest and the least regulated one, is $\{X \rightarrow M \rightarrow F\}$. According to this pathway, X introduces the new varieties to national market, and private marketing agents M market the varieties by providing extension services to farmers.

Decision makers can use the Linkage Matrix *to identify the constraints facing the AISA*. For instance, the public and private components of the AISA interact at a low tone. This is reflected by the fact that the system requires intermediary organizations, such as marketing associations, farmers' organizations, trade and commerce organizations, etc. to bring together the diffuse elements of the system. At present, such organizations are at a very early stage of development, demanding regulatory changes to ease their operations (see Temel, Janssen, and Karimov, 2001). More specifically, links between the components (I, M, F, P, R) could be strengthened through policy dialogues that would allow the intermediary organizations to pass information from (I, M, F) to (P, R).

CONCLUSIONS

This study introduces a graph-theoretic method for assessing linkages between components of a system and applies it to characterize the AISA. This method is especially useful for examining the interactive structure of the AISA. It promises wide applications among policy makers who are interested in assessing alternative innovation policies and/or programs by identifying effective pathways of interactions between the components and the constraints that hinder these interactions.

Application suggests that ample scope exists for the design and implementation of linkage mechanisms among the components of the public system, including Policy, Research, Education, and Credit. This is reflected in Table 1 that the cells representing the binary interactions between these 4 components lack specific linkage mechanisms. A second observation from Table 1 is the infrequent use of specific linkage mechanisms between the public components (including Policy, Research, Education, and Credit) and the private components (including Extension, Private Enterprise, Private Farm, Private Consultancy, and External Assistance). This is revealed by the empty off-diagonal cells representing the interactions between the public and private components, further implying the need for intermediary organizations to facilitate quick flow of knowledge between the public and the private components. But the development of such organizations calls for an enabling institutional environment.

Regarding the establishment of cross-organization linkages, the interviewees very often indicated financial and human resource constraints as the key barriers.⁷ Furthermore, the authors have commonly observed during the structured interviews with research policy makers, managers, and scientists that a more proactive approach is needed for collaborative research with international organizations. Such need was manifested by the fact that almost all research programs and projects to date have been initiated by the international organizations.

More specifically, analysis of the current study indicates two patterns in the AISA. First, D is the most dominant, and X and R are the most interactive components. On the other hand, P is the most subordinate component, which is followed by F (see Figure 3). Second, with respect to the use of linkage mechanisms, the leading components include (D, I, X, F), while (P, R, M, E) use these mechanisms less often (see Figure 4). This can be attributed to the fact that X, D, and I are mostly engaged in project activities designed for specific objectives, and that the working style of organizations in D and X also requires involving parties to operate with work plans and programs. Interestingly, however, the components P, R, M, and E do not utilize as many linkage mechanisms as expected, implying unorganised activities and weak management.

What remains to be addressed is to develop methodological guidelines in order to assess national institutional set-ups with the view of obtaining comparable results at the international levels. As argued by Capron and Cincera (2000), the present literature does not report any operational guidelines regarding the assessment of institutional linkages underpinning national innovation systems. Such guidelines could also be used as a benchmarking approach in the management of agricultural, science, and technology policies. An equivalently

⁷ This conclusion refers to the information obtained from Form #3 of the questionnaire given in Temel, Janssen, and Karimov (2001).

important issue, which has not received enough attention in the literature, is, as argued by (Nelson, 1993), the need for well articulated and verified analytical frameworks linking institutional arrangements to technological and economic performance.

Two weaknesses of the method introduced remain to be topics of future research. First, quantitative representation of organizational interactions, like we attempted in this study, will be questionable especially when rare but influential interactions take place between the organizations. An interaction may only be infrequent but of crucial importance, whilst some, such as committee meetings, may occur frequently, but may be of low impact. Second, the development of solid quantitative measures of policies (or strategies) and the testing of specific hypotheses still require a theoretical formulation of organizational objectives and constraints. This calls for a reformulation of the systems approach as a mathematical model.

REFERENCES

- Azerbaycan Respublikasi Kend Teserrufati Nazirligi (ARKTN). 2000. Azerbaycan Respublikasinin Kend Teserrufatina Dair Icmal. Azerbaycan Respublikasi Kend Teserrufatinda Ozel Bolmenin Inkisafina Yardim Agentligi. Baku: Azerbaycan.
- Capron, H., & Cincera, M. 2000. Assessing the institutional set-up of national innovation system. OECD. [On Line].
- Cormen, H. T., Leiserson, E. C., & Rivest, L. R. 1990. Introduction to algorithms. Cambridge: The MIT Press.
- Deborah, M. S., Kaimowitz, D., Sayce, K., & Chater, S. 1989. The technology triangle: Linking farmers, technology transfer agents, and agricultural research. The Hague, Netherlands: ISNAR.
- European Commission. 2000. Innovation policy in a knowledge-based economy. A merit study commissioned by the European Commission. Brussels, Belgium: Enterprise Directorate General.
- Freeman, C. 1987. Technology policy and economic performance: Lessons from Japan. Pinter, London.
- Freeman, L. C. 1997. Uncovering organizational hierarchies. Computational and Mathematical Organization Theory, 3(1):5-18.
- Freeman, L. C. 2000. Using available graph theoretic or molecular modelling programs in social network analysis. [On Line: <http://tarski.ss.uci.edu/new.html>]
- Hudson, J. A. 1992. Rock engineering systems: Theory and practice. London: Ellis Horwood Limited, Chichester, U.K.
- Leontief, W. W. 1951. The structure of American economy, 1919-1939. Fair Lawn, NJ: Oxford University Press.
- Manescu, M. 1980. Economic cybernetics. Great Britain. Abacus Press.
- Metcalf, S. 1995. The economic foundations of technology policy: Equilibrium and evolutionary perspectives. In P. Stoneman (Ed.). Handbook of the Economics of Innovation and Technical Change, pp-409-512, Blackwell, Oxford.
- Miller, G. A. 1956. The magical number seven, plus or minus two: Some limits on our capacity for processing information. The Psychological Review, 63(2):81-97.
- Murota, K. 1987. Systems analysis by graphs and matroids: structural solvability and controlability. Berlin: Springer-Verlag.
- Nelson, R. R. (Ed.). 1993. National innovation systems: A comparative analysis. New York: Oxford University Press.
- OECD. 1997. Boosting innovations: The cluster analysis. Paris, France: OECD.

OECD. 1999. Managing national innovation systems. Paris, France: OECD

Owen, D., Mered, M., Mikkelsen, J., Prokopenko, V., Inchauste, G., and Singh, M. 2000. Azerbaijan Republic: Recent economic developments and selected issues (IMF Staff Country Report No. 00/121). Washington, D.C.: European II Department, the IMF.

Pearl, J. 1995. Causal diagrams for empirical research (with discussion). *Biometrika*, 82, 669-690.

Richardson, T. S. 1999. Chain graphs and symmetric associations. In *Learning in graphical models* by Michael L. Jordan (Ed.), The MIT Press, Cambridge, Massachusetts.

Smith, K. et al. 1996. The Norwegian national innovation system: A pilot study of knowledge creation, STEP Report, Oslo.

Scott, J. 2000. *Social network analysis: A handbook* (2nd Ed.). London, UK: Sage Publications.

Shrum, W. 1997. A social network approach to analysing research systems: A study of Kenya, Ghana, and Kerala (India) (Briefing Paper No. 36). The Hague, Netherlands: International Service for National Agricultural Research.

Temel, T., Janssen, W., and Karimov, F. 2001. Agricultural innovation system of Azerbaijan: An assessment of institutional interactions (Discussion Paper No. 01-3). The Hague, The Netherlands: ISNAR.

Tull, D. S., and Hawkins, D. I. 1984. *Marketing research: measurement and method*. New York: Mac Millan.

Figure 2. Agricultural innovation system – organizational structure

| | | | | | | | | |
|---|---|---|--|--|--|--|---|---|
| Policy Component (P) (Reorganization) | Formal & weak | Formal & weak | Formal & weak | Mixed & weak | | | | Formal & medium Priority setting Program development Program review |
| Formal & weak | Research Component (R) (Reorganization) | Formal & weak | | Mixed & weak | Mixed & medium | Informal & medium | Informal & medium Information sharing Problem diagnosis Technology diffusion Exchange of staff | Formal & weak Workshops/seminars Information sharing Personnel training |
| Formal & weak | Formal & weak | Education Component (E) (Reorganization) | | | | Informal & weak | Informal & medium | Formal & weak Workshops/seminars Information sharing |
| Formal & weak | | | Credit Component (C) (Reorganization) | | | | | Formal & weak |
| Formal & medium Information sharing | Formal & medium Information sharing | | | Extension and Information Component (I) | | Formal & medium Program development Problem diagnosis Priority setting Tech diffusion/demonstration Training | Formal & medium Program development Tech. diffusion Info&finance sharing Workshops Seminars | Formal & weak Tech. diffusion & demonstration Information sharing |
| Formal & medium | Informal & medium | | | | Private Enterprise Component (M) | Mixed & medium Tech. demonstration Training | | Mixed & weak Program development Tech. development Workshops |
| Formal & medium Information sharing | Informal & medium Information sharing Problem diagnosis Technology diffusion Exchange of staff | Informal & weak Information sharing | | | Mixed & weak Tech. demonstration Training | Private Farm Component (F) | | |
| Formal & medium Information sharing | Informal & medium Information sharing Problem diagnosis Technology diffusion Exchange of staff | Mixed & medium Information sharing | | Formal & weak Program development Sharing of info. & finance Workshops | Informal & weak | Mixed & medium Problem diagnosis Priority setting Technology diffusion & demonstration | Private Consultancy Component (D) | Formal & weak Program development Tech. diffusion Info & finance sharing Workshops |
| Formal & medium Priority setting Program development Program review | Formal & weak | | | Formal & strong Priority setting Program development Technology development Technology diffusion and demonstration Information sharing | Mixed & weak | Formal & medium Problem diagnosis Program development Tech. demonstration Information sharing Training | Formal & medium Program development Tech. diffusion Info&finance sharing Workshops | External Assistance Component |

Table 1. Linkage matrix

Appendix

| Linkage mechanisms | | |
|---------------------------|---|-------------|
| Linkage types | Linkage mechanisms | <i>Code</i> |
| A. Planning & Review | Joint problem diagnosis | 1 |
| | Joint priority setting and planning | 2 |
| | Joint program development | 3 |
| | Joint review and evaluation | 4 |
| B. Program Activities | Joint technology development | 5 |
| | Joint technology evaluation | 6 |
| | Joint technology demonstration | 7 |
| | Joint technology diffusion | 8 |
| C. Resource Use | Exchange of personnel/staff rotation | 9 |
| | Joint use of facilities (e.g., laboratories) | 10 |
| | Sharing of financial resources and materials | 11 |
| D. Information | Sharing of information | 12 |
| | Joint use of information sources (e.g., lib., Internet) | 13 |
| | Joint reporting | 14 |
| | Joint publication of documents | 15 |
| | Joint seminars and workshops | 16 |
| E. Training | Joint training of students | 17 |
| | Joint training of staff (short-term) | 18 |

Strength of linkages with other agents

| Components | Agents | Strength | | | |
|-------------------------------|--|----------|---|---|---|
| | | S | M | W | N |
| Policy (P) | Parliament's Agricultural Committee | | | | |
| | Cabinet of Ministers Agricultural Comm. | | | | |
| | Ministry of Agriculture | | | | |
| | Ministry of Science & Education | | | | |
| | MOA Division(s) of Agr. Sci., Ed. & Ext. | | | | |
| Finance (C) | Ministry of Finance | | | | |
| Research (R) | Biological Sciences, Academy of Sciences | | | | |
| | Agricultural research council (apex) | | | | |
| | Agricultural research institutes | | | | |
| | Research departments at institutes | | | | |
| | Researchers | | | | |
| Extension and Information (I) | Agricultural extension offices | | | | |
| | Extension program leaders | | | | |
| | Extension specialists or agents | | | | |
| | Agricultural comm. unit (radio/news) | | | | |
| Education (E) | Agricultural & Veterinary Academies | | | | |
| | Departments at Academies | | | | |
| | Professors | | | | |
| | Post-graduate students | | | | |
| Farm production (F) | Large farmer organizations | | | | |
| | Small farmer organization | | | | |
| | Large farms (Jt. Stock Co's & Coop's) | | | | |
| | Small commercial farmers | | | | |
| Credit (C) | MOA rural credit program | | | | |
| | National bank with rural credit line | | | | |
| | Local bank with rural credit line | | | | |
| Input supply (M) | Seed supply unit | | | | |
| | Fertilizer supply unit | | | | |
| | Pesticide supply unit | | | | |
| | Equipment supply unit | | | | |
| Processing (M) | Public processing units | | | | |
| | Private processing firms | | | | |
| Marketing (M) | Public marketing units | | | | |
| | Private marketing firms | | | | |
| External assistance (X) | Donor/development agencies (e.g., TACIS) | | | | |
| | International NGOs/PVOs | | | | |
| | IARCs (e.g., ICARDA) | | | | |
| | International networks and consortia | | | | |

Linkage Strength – S = Strong; M = Medium; W = Weak, N = None

Linkage mechanisms used by your organization with other agents

| Components | Agents | Linkage Codes <See list 3> | | | | | |
|-------------------------------|--|-------------------------------|--|--|--|--|--|
| Policy (P) | Parliament's Agricultural Committee | | | | | | |
| | Cabinet of Ministers Agricultural Com. | | | | | | |
| | Ministry of Agriculture | | | | | | |
| | Ministry of Science & Education | | | | | | |
| | MOA Division(s) of Agr. Sci., Ed& Ext. | | | | | | |
| Finance (C) | Ministry of Finance | | | | | | |
| Research (R) | Agricultural research council (apex) | | | | | | |
| | Agricultural research institutes | | | | | | |
| | Research departments at institutes | | | | | | |
| | Researchers | | | | | | |
| Extension and Information (I) | Agricultural extension offices | | | | | | |
| | Extension program leaders | | | | | | |
| | Extension specialists or agents | | | | | | |
| | Agricultural communications unit | | | | | | |
| Education (E) | Agricultural & Veterinary Academies | | | | | | |
| | Departments at Academies | | | | | | |
| | Professors | | | | | | |
| | Post-graduate students | | | | | | |
| Farm production (F) | Large farmer organizations | | | | | | |
| | Small farmer organization | | | | | | |
| | Large farms (Jt. Stock Co's/Coop) | | | | | | |
| | Small commercial farmers | | | | | | |
| Credit (C) | MOA rural credit program | | | | | | |
| | National bank with rural credit line | | | | | | |
| | Local bank with rural credit line | | | | | | |
| Input supply (M) | Seed supply unit | | | | | | |
| | Fertilizer supply unit | | | | | | |
| | Pesticide supply unit | | | | | | |
| | Equipment supply unit | | | | | | |
| Processing (M) | Public processing units | | | | | | |
| | Private processing firms | | | | | | |
| Marketing (M) | Public marketing units | | | | | | |
| | Private marketing firms | | | | | | |
| External assistance (X) | Development agencies (e.g., TACIS) | | | | | | |
| | International NGOs/PVOs | | | | | | |
| | IARCs (e.g., ICARDA) | | | | | | |
| | International networks and consortia | | | | | | |

Abbreviations and Acronyms

| | |
|---------|--|
| ASCA | Agrarian Science Center of Azerbaijan |
| ADCP | Agricultural Development and Credit Project |
| ADMAP | Agricultural Development Mountainous Areas Project |
| ARB | Agricultural Research Board |
| AS | Academy of Sciences |
| ASC | Agricultural State Colleges |
| ASDPAS | Agency for Support to the Development of Private Agricultural Sector |
| AzAA | Azerbaijan Agricultural Academy |
| CGS | Competitive Grants System |
| ERS | Economic Reform Center |
| FPP | Farm Privatization Project |
| HDSREPT | Head Dept. Scientific Research, Education, and Personnel Training |
| IARC | International Agricultural Research Center |
| ICARDA | International Center for Agricultural Research in Dry Areas |
| ICSC | Information and Consulting Services Center |
| IDAD | International Development Agencies and Donors |
| IFAD | International Fund for Agricultural Development |
| GTZ | German Technical Support Society |
| MoA | Ministry of Agriculture |
| MoEd | Ministry of Education |
| MoED | Ministry of Economic Development |
| MoEc | Ministry of Ecology |
| MoF | Ministry of Finance |
| MoT | Ministry of Taxes |
| NGOF | Non-governmental Organizations Forum |
| nAPC | Non-agricultural Private Colleges |
| nASC | Non-agricultural State Colleges |
| NARS | National Agricultural Research System |
| NGO | Non Governmental Organization |
| PACF | Private Agro-Consulting Firms |
| PrU | Private Universities |
| RC | Regional centers |
| RES | Regional Experimental Stations |
| RI | Research Institutes |
| SCAR | State Committee for Agrarian Reforms |
| SCADPF | State Committee for Assistance to Development of Private Farms |
| SCSEC | State Committee on Science, Education, and Culture |
| SSF | State Seed Farms |
| SCAI | State Committee for Amelioration & Irrigation |
| SLC | State Land Committee |
| SU | State Universities |
| SCST | State Committee on Science and Technology |
| SCC | State Customs Committee |
| TACIS | Technical Assistance Committee for Independence States |
| USAID | United States Agency for International Development |
| UNDP | United Nation Development Program |
| WB | World Bank |