

Agricultural Biotech as a Complex Adaptive System **(Primary Investigator: Steve Sonka)**

Goals: The primary purpose of this project is to explore whether viewing technology development and adoption as a complex adaptive system (CAS) can provide useful insights that further our understanding of innovation and of the processes by which innovations, such as agricultural biotechnology, are socially evaluated. This framework explicitly recognizes that successful innovation is co-determined by the forces of technology and by those of society. The direct result of the effort will be a report based upon literature review, synthesis of associated methods and a research workshop/symposium focusing on "Agricultural Biotech as a Complex Adaptive System". If this initial work produces promising results, additional efforts will be pursued to implement the framework with decision makers in both the public and private sectors.

Procedures: This section will provide a brief overview of complex adaptive systems and approaches employed to employ the CAS concept. Then the specific activities proposed for this project will be detailed.

Pascale (1999) specifies that complex adaptive systems have four characteristics. They are non-hierarchical, being comprised of many actors operating in parallel. Second, there are multiple, shifting layers of organization and structure. Third, subject to the third law of thermodynamics, CAS's can wind down over time unless replenished with energy. Fourth, CAS's exhibit a capability for pattern recognition and learning.

Of particular interest for the study of technology development and adoption, complexity science focuses on non-linear outcomes driven by rapid phase transitions and co evolutionary forces (fueled by positive feedback loops) set in force by seemingly inconsequential instigating events (McKelvey, 2004). Sometimes referred to as strange attractors, the interplay of these inconsequential and seemingly unrelated events, when combined with positive feedback loops, seem to be particularly fruitful.

Although seemingly related in several respects, system dynamics has emanated from differing roots than that of complexity. However, this area of study has elements that are attractive for analysis of technology development and evolution. System dynamics modeling has principles rooted in electrical engineering analogs applied as a problem solving methodology to managed systems. Forrester (1961) led the initial work in the area. In the early 1990s, Senge's (1990) emphasis on system thinking as a key to learning organizations renewed academic and popular interest in system dynamics. Relative to technology development and adoption, system dynamics thinking emphasizes such important factors as explicit specification of system boundaries, the existence of both positive and negative feedback loops, the role of time, the need to separately incorporate causal ambiguities and uncertainties.

The activities proposed for this project will be accomplished within the five sequential steps identified below:

1. Initial conceptualization: A major strength of the University of Illinois at Urbana-Champaign is its breadth of expertise across a range of disciplines and domains. Relevant expertise from engineering, management sciences, economics and agricultural economics, geography and other areas will be drawn upon to insure that the proposed effort undertakes the highest priority set of activities. The process of soliciting this information will be informal (small group meetings) which can be completed rapidly and with minimal expenditures.
2. The proposed effort needs a solid foundation based upon prior research in the domains of complexity and system dynamics. A major component of the study will focus on documenting

the extent and success of prior analyses applying these concepts to topics similar to the development and adoption of agricultural biotechnology. Lessor effort will be devoted to monitoring the literature on adoption and societal acceptance of agricultural biotechnology.

3. Approximately six to nine months into the project, the results from steps one and two of the project will be summarized as a draft conceptual framework. This draft framework will focus on findings that have the potential to lead to “actionable” methods and tools which would provide insights of potential value to private and public decision makers charged with advancing agricultural biotechnology.

4. A research workshop/symposium will be conducted to critique and augment the framework developed in step three. This event will be multidisciplinary in nature with participation from the biologic sciences as well as from the complexity and system dynamics domains. Participation of research administrators from both the private sector and academia will be arranged. The symposium will be a two day event with approximately 15 participants. To reduce travel expenditures the majority of the group will be from the University of Illinois Urbana-Champaign campus with approximately one third of the group from outside that campus. The symposium itself will be an intense working meeting. The participants will have been provided the draft conceptual framework prior to the event. The initial components will be devoted to clarifying specific points within the framework and then in testing those components relative to agricultural biotechnology and its adoption experience. The participants will then be challenged to enhance the framework through experiences conducted in smaller working groups and as an entire body. Staff of the National Soybean Research Lab will organize and facilitate the symposium, employing advanced information technology-based tools to maximize effectiveness of the event.

5. A white paper, "Agricultural Biotech as a Complex Adaptive System", will be produced immediately upon conclusion of the symposium. Additional research reports, presentations, and journal articles will be produced.

Timelines: The bulk of the activities of this project will be completed in years one and two of the grant. *Year 1:* Steps 1 thru 4 will be completed. It is envisioned that the research symposium will occur in the spring of 2006. *Year 2:* Step 5 will be completed

Impact of Agricultural Biotech as a Complex Adaptive System: The application of biotechnology to soybean production already has had significant impacts, both in the US and globally (ISAAA, 2005). However, the impacts to date have resulted primarily from extensive application of varieties tolerant to specific categories of herbicides. The full promise of biotechnology for soybeans will be fulfilled only when so-called second generation varieties are available in combination with disease resistant attributes and widely adopted.

Agriculture’s experience with biotechnology enhanced varieties has demonstrated that farmer acceptance of the agronomic benefits of those varieties is not sufficient to assure marketplace success globally. Indeed societal acceptance also has been a dominant and controversial aspect of the last decade’s experience with genetically enhanced soybeans. Considering economic efficiency and induced innovation, acceptance of genetically enhanced crops would seem not to be a ready target for societal controversy. Farmers desire to reduce costs, raise output, and reduce the extent of environmental insult caused by agricultural practices. The calculus of determining the direct benefits of a new technology is well understood by both commercial and peasant farmers, and society relies upon a continually more productive agriculture to provide products within a complicated food system. As urbanization continues to

embrace a larger proportion of the world's population, the need intensifies for further innovation to support the long supply channels that the natural environment not be degraded in the process of producing food and fiber.

The expectation was that the success of the first generation products of agricultural biotechnology would be determined in the agricultural marketplace, where performance would be the primary form of evaluation and societal interests are considered. Rather extensive regulatory processes, both related to research and development activities and to effects on the environment and food safety, would provide the context in which society's non-market interests would be protected. Albeit, societal acceptance globally has and continues to be contentious. These controversies have the potential to affect the future path and pace of the evolution of agricultural biotechnology and, therefore, the potential for this technology to provide benefits in the soybean sector and to society.

The primary purpose of this project is to explore whether viewing technology development and adoption as a complex adaptive system (CAS) can provide useful insights that further our understanding of innovation and of the processes by which innovations, such as agricultural biotechnology, are socially evaluated. Determination of a more robust framework will provide technology proponents as well as societal decision makers an improved means to evaluate future genetically enhanced products in the soybean sector.