

## **Factors Affecting the Economic Feasibility of the Biological Control of Weeds**

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### *Abstract*

Studies examining the economics of biological control of weeds have focused on conceptualization of the broad, societal benefits that justify public expenditure on biocontrol research and implementation. Consideration of the acceptability and desirability of biological control from the perspective of its users consequently has been overlooked. However, it is the support of eventual users of a biocontrol technique that ultimately determines success. Assessment of economic feasibility, the capability of a biocontrol technique to yield equivalent or greater net returns to users than do current weed control practices, is an important first step in evaluating and selecting approaches for research or implementation. Economic feasibility is greatest for situations under which: (a) target weed damage is perceived by potential biocontrol users as an economic problem; (b) the target weed is a singly-occurring major weed problem on high-valued land but causes low to moderate damages per weed individual; (c) current methods for control of the target weed are either unavailable, or their direct and indirect costs are high; (d) the biocontrol agent is technically effective; (e) the effect of the agent on the weed is rapid and reliable; (f) users' direct and opportunity costs of employing the biocontrol tactic are low; and (g) the interrelationship of these characteristics results in higher net returns to the use of biological control than available nonbiological alternatives. Once economic feasibility has been verified, the biocontrol targeting process can further be refined by examining the commercial potential and/or broader societal impacts of economically feasible tactics' implementation.

## **Facteurs Influant sur la Faisabilité Économique de la Lutte Biologique Contre les Plantes Nuisibles**

Les études portant sur les aspects économiques de la lutte biologique contre les plantes nuisibles se sont concentrées sur la conceptualisation des avantages d'ensemble pour la société justifiant les dépenses publiques en recherche et en application de la lutte biologique. On n'a donc pas tenu compte des aspects d'acceptabilité et de désirabilité de la lutte biologique du point de vue des utilisateurs. Cependant, c'est l'appui des utilisateurs éventuels d'une technique de lutte biologique qui détermine en fin de compte son succès. L'évaluation de la faisabilité économique, la capacité d'une technique de lutte biologique à permettre aux utilisateurs de réaliser des bénéfices équivalents ou supérieurs à ceux permis par les pratiques courantes de lutte contre les plantes nuisibles, constitue une première étape importante dans l'évaluation et le choix des méthodes de recherche et d'application. La faisabilité économique est particulièrement nécessaire dans les cas où (a) les utilisateurs éventuels de la lutte biologique considèrent les dommages causés par la plante nuisible cible comme un problème économique; (b) la plante nuisible visée constitue le seul problème important de plantes nuisibles sur les terres à valeur élevée, mais ne cause que des dommages faibles à modérés par plant individuel; (c) les méthodes courantes de lutte contre la plante nuisible visée sont inaccessibles ou leurs coûts directs et indirects sont élevés; (d) l'agent de lutte biologique est techniquement efficace; (e) l'effet de l'agent sur la plante nuisible est rapide et fiable; (f) les coûts directs et occasionnels des utilisateurs reliés à l'emploi de la méthode de lutte biologique sont faibles; et (g) la corrélation de ces caractéristiques se traduit par des bénéfices plus élevés avec la lutte biologique qu'avec les méthodes de lutte non biologiques disponibles. Une fois la faisabilité économique vérifiée, on peut continuer d'affiner le ciblage de la lutte biologique en examinant les possibilités commerciales et les effets d'ensemble sur la société de l'application des méthodes économiquement faisables.

## Introduction

During a time when agricultural research funding is limited, competition among areas of investigation is fierce, and matriculation of agricultural scientists is ebbing, it is especially important to focus applied research on techniques that have a high probability of successful implementation. Assessment of the potential economic feasibility of technological possibilities is a valuable input to the research decisionmaking process. Consideration of factors affecting economic feasibility of biological control of weeds can help guide research efforts towards those techniques most likely to successfully demonstrate the potential for biological control of weeds.

The economic performance of biological control technology is determined by the interactions among the populations of at least three species — the biological control agent; the pest organism; and the human population whose activities are disrupted by presence of the pest. In agricultural systems, man's activities involve additional species — the crop or livestock populations affected by the pest. But these commercial species are important only in terms of how they contribute to the achievement of man's objectives.

While much has been written about the conceptual aspects of evaluating biological control of weeds (Andres 1977; Harris 1980; Tisdell *et al.* 1984), little work actually has been done to accurately quantify the benefits and/or cost of weed biocontrol. What economic accounting has been achieved (e.g. Cullen 1978; Harris 1979) focuses on biological control research project benefits and costs. Measurement of net expected economic returns to the primary beneficiaries (users) of the biocontrol technique, a critical clue to the probable success of the technology itself, tends to be ignored or is so deeply imbedded in a broader attempt at project justification that it is inextricable for research decisionmaking purposes.

This paper explains how information obtained from user-oriented economic feasibility studies differs from the results of project justification efforts, why assessments of economic feasibility are independently valuable in selecting weed and biocontrol agent subjects for study, and what is required to examine the economic feasibility of biological control possibilities.

## The Concept of Economic Feasibility

Economic feasibility here refers to the capability of a given biological control technique to yield equivalent or greater net returns to its user as do current weed control practices. The concept is user-oriented. The user is the farmer, rancher, irrigation commissioner, etc., who directly experiences the weed problem. Net returns are the benefits obtained by the user from weed control, minus the costs the user faces to achieve control. The nature of these benefits and costs is determined by the objectives of the user. In the case of users whose objective is to maximize profit obtained from an economic enterprise (such as crop production), costs and benefits are fairly straightforward and measured in monetary terms. Users whose objective is to minimize risk (as in the case of subsistence farmers requiring a minimum level of food production to avert disaster) view benefits and costs differently. This group attaches a higher than strictly monetary cost to techniques that have even minimal risk of failure. Users facing a fixed budget may be more concerned with cost minimization, an objective through which benefits of a technique are discounted as cost of the technique approaches or exceeds a maximum amount.

The importance of the economic feasibility concept is that users who cannot expect to gain, by whatever criteria, from the use of a particular weed control technique, have little or no incentive to adopt or utilize, or preserve the potentially broader benefits of

the technique. Thus, success of any given biological control alternative is ultimately judged by the economic feasibility of its implementation.

The concept of economic feasibility is narrow to the extent that it does not incorporate the entire range of benefits and costs to society. However, for two important reasons, assessment of economic feasibility is a logical first step in judging overall implications of alternative methods for biological control of weeds. First, if a biological control technique is not economically feasible from the perspective of its target user group, there is no need to estimate broader economic implications of the technique because it will not be adopted (unless the user is subsidized). Full accounting of the total environmental, market, and other social costs of a biocontrol approach involves considerable effort. This effort is neither necessary nor justifiable unless the technique's basic economic feasibility is first established. By making feasibility assessment a first step in evaluation and comparison of alternative techniques, unnecessary work can be avoided.

Secondly, information needed to estimate economic feasibility is a prerequisite for examining the full economic implications of a technique's implementation. Benefit/cost analysis incorporates both private and public gains and losses, and determines whether research and development or implementation of a technique is justifiable when total societal economic returns are considered. Economic feasibility assessment provides the measures of private benefits and costs that are components of a benefit/cost analysis.

#### **Factors Affecting Economic Feasibility**

A range of biotic, abiotic, social, and economic factors interact to determine the comparative economic advantage or disadvantage of biological control (Reichelderfer 1981). In the following discussion, the independent effects of those factors most critical to the economic feasibility of the biological control of weeds are reviewed.

#### *Impact of Target Weed on Economic Activity*

By definition, a weed is a plant out of place. But, the effect of this displacement in an economic system can range from insignificant to devastating. A number of different relationships determine the extent of impact. In selecting the best set of weeds for biocontrol research, each of the following components must be examined.

*Weed status.* In what way does the weed interfere with man's activities? What value does the affected group place on this interference? These are two of the questions to be addressed in examining the status of a given weed in an economic system. The first is primarily a function of losses — such things as reduction in crop yield, product contamination, reduced weight-gain or fertility, poisoning of livestock, decreased water flow, or decline in land value. While estimation of physical losses is essential, it is equally important at early stages in the consideration of various weeds as biocontrol targets, to determine how the group affected by the weeds perceives the issue of loss. Weed severity needs to be based on sociological, psychological, and economic criteria distinct from purely physical damage relationships. Bypassing an assessment of the potential biocontrol user group's perception of the weed can lead to erroneous assumptions regarding the weed's status. For example, Hildebrand (1981) reports the case of Guatemalan farmers who rejected recommendations for control of weeds that limit vegetable yield. The reason for rejection was that the farmers used the 'weed' species as a supplemental livestock feed source following vegetable harvest. To the farmers, the disvalue of vegetable yield reduction was outweighed by the value of feed supply. This illustrates why it is important to assure that the physical damage from

weed infestation is in fact translated into an economic problem. The effort required for effective biological control of nuisance weeds may not be justifiable from the point of view of the tactic's users.

It is the combination of all uses to which land is devoted (e.g. crop and livestock production, or drainage and recreation) that determines the land value and, thus, the disvalue of its infestation with weeds. All else equal, the greater the value of weed-infested land in its current uses, the higher the probability a biological control technique will be economically feasible.

The generally positive relationship between the value of losses from weeds and the economic feasibility of weed biocontrol is tempered by a negative relationship between the severity of damage per weed individual and the economic benefit of biological control. By its very nature, biological control allows a low, steady-state level of the weed population to survive. If the damage per individual in that steady-state population is high, even high rates of reduction achieved by the biocontrol agents may not be sufficient to drop the pest population below the economic injury level (Reichelderfer 1981). Weeds that cause moderate or low levels of damage per individual possess high economic injury population levels, require lower proportional control and, thus, are targets for which control is more likely to be economically feasible.

*Availability and cost of current weed control.* The economic feasibility of biological control is greatest in cases for which there is no other weed control option. The likelihood of economic feasibility also is high for the biological control of weeds for which current control costs are high. Agricultural weed control costs can include the effects of having to synchronize or delay field operations as well as the direct costs of herbicide materials and/or machinery, fuel and labor to apply materials or clean weed seed from products.

The opportunity cost of weed control (the value that time or managerial effort devoted to weed control could produce if engaged in other activities) can be very high, especially in less developed regions. The requirement of labor for weed control often limits the area of production in traditional farming systems (Koch *et al.* 1982). For example, in the maize/bean production systems of the Jinotega region of Nicaragua, averages of 13–37 man-days/ha are devoted to manual weeding. Labor for weeding represents 21 to 35% of total farm family labor available, there, for crop production (Tienhoven *et al.* 1982). (Koch *et al.* [1982] cite evidence indicating that from 30 to 61% of farmers' time in various African cropping systems is spent on weeding.) Labor is the factor that limits crop production possibilities in the Jinotega region (Tienhoven *et al.* 1982) and in similar regions where farm labor is mainly family-based. If labor required for weeding was reduced, additional hectareage could be cultivated and the income derived from farming much greater. Thus, although the market value of labor may be low, its value in relation to increased production possibilities can be quite high.

Both the direct and indirect costs of weed control in production enterprises need to be considered when assessing economic feasibility of biological control. If the sum of direct and indirect costs of current control is low, the potential feasibility of new alternative weed control methods also is relatively low.

*Net effect of weed losses and control costs.* Adding together costs of current control and value of losses that occur despite control efforts provides a measure of a weed's net impact on the target user group. Tradeoffs can occur between loss and cost factors in determining net effect. A weed population that causes moderate damage but is expensive to control may have as large an impact on the user as one that causes severe losses but is easy to control by current methods. The net economic effect of losses and costs under current control is the benchmark against which the expected net benefit of biological control needs to be compared.

### *Technical Effectiveness of Biological Control Option*

A range of taxonomic and ecological characteristics of the target weed and potential biological control agent affect the probability that a given biological control technique will be a technical success in reducing the weed problem. Included among the factors DeLoach (1978) recommends should be considered in evaluating the biocontrol success potential for various weeds are whether the weed is: introduced or native; annual or perennial; a pest in a stable or disturbed habitat; and the site of origin of the weed genus, number of species of the weed genus in the control area, and the number and importance of related plant species in the area (DeLoach 1978). Harris (1973) and Goeden (1983) list and discuss a number of characteristics of insect agents that affect the potential success of an agent's use in providing adequate weed control. Many of the characteristics they identify, including phenology of attack, host specificity, extrinsic mortality factors, compatibility with other control agents, and evidence of effectiveness as a control agent, apply equally as well to consideration of higher animals or plant pathogens as biocontrol agents.

These characteristics of the weed and biocontrol agent are directly related to potential economic feasibility. As technical effectiveness increases and all else is constant, the probability that the technique is economically feasible improves. However, technical effectiveness should not be used as the sole basis on which to judge economic feasibility. Depending upon the costs required to achieve predicted effectiveness of control by biological means, and the relationship of the method's net returns to those obtained by current methods, a highly effective biological control technique may, or may not be economically feasible.

### *Pest Spectrum*

An additional characteristic of the target weed — its relationship with coexisting weed problems — and host-specificity of the biocontrol agent interact to further affect economic feasibility of biological control of the weed. Simultaneous occurrence of several weeds of the same general type has a negative impact on economic feasibility of species-specific biological control techniques. If chemical or cultural methods can control all coexisting weed species of a certain type, and if the available biocontrol agent is specific to only one of these species, use of the biological control alternative, all else constant, will likely result in little or no relative benefit. Control action still would have to be taken against the coexisting weeds. If that action, like the use of a broad-spectrum herbicide, is both necessary and effective against all coexisting weeds, any cost of utilizing the biocontrol agent would be unjustified. Thus, economic feasibility of biological control is most likely to be found for singly occurring major weed species.

### *Variability and Rapidity of Biological Control Agent's Effect*

Many potential weed control users will be as concerned with the variability of a biocontrol tactic's effect as they are with the average expected effect. A technique that consistently reduces weed populations by around 60% a year will be viewed as more desirable than one that reduces the weed population by 90% one-third of the time, 75% one-third of the time, and 20% one-third of the time, even though both give similar average control over time. Uncertainty about the technique's effect in a given time period increases the risk of employing it. Risk-averse users, especially, prefer consistency over the possibility of periodically outstanding effect. They will actually pay a premium (a higher cost) for a technique that has consistent results. The risk associated with using a highly variable biological control agent adds a user cost that adversely affects its economic feasibility.

Another characteristic of weed control that is valued by risk-averse decisionmakers is a quick and readily apparent reduction in the weed population. If for example, a biological control tactic requires the user to forego herbicide application over the period of time required for endemic establishment of a plant disease, the user may perceive that he or she is risking a loss by waiting for an uncertain benefit. This means the user cost of the technique is greater than its direct cash outlay requirements.

Risk and uncertainty are important features of economic feasibility. The more variable or otherwise risky a technique is viewed, the lower its economic feasibility from the perspective of its potential users.

#### *User Costs of Biological Control*

Obviously, the cost required to effectively employ a biological control technique weighs heavily in users' determination of the technique's economic feasibility. All else equal, the lower this cost to the user, the greater the economic feasibility of the technique.

In general, classical biological control is likely to require lower user costs than augmentative or inundative biocontrol techniques. However, even when the biocontrol agent is produced and distributed by a public body, free of direct charge to beneficiaries, some user costs may exist. This is particularly true for crop protection. Many of the component practices making up a cropping system influence or are influenced by weed infestation (Koch *et al.* 1982). When the status of a weed pest in a production system changes due to biological control, changes may have to be made in the date of planting, type or timing of tillage operations, methods of control for remaining pests, or other production practices to accommodate and preserve the benefit of the biocontrol agent. If, for example, the weed biocontrol agent is an insect that is susceptible to insecticides currently used against insect pests, the user may be faced with a tradeoff between weed and insect pest control. Since changes in production practices in turn can affect the yield and/or quality of the commodity being produced, such changes, and their effects, resulting from biological control need to be anticipated and assessed. While in some cases, they will result in a savings to the user, in others they will represent a cost.

Another factor to consider in determining whether or not beneficiaries of classical biological control will face new costs is the type of plant likely to fill the niche formerly occupied by the target weed. A proportion of the benefits of biocontrol may be superseded by new problems arising as other weeds increase to occupy the habitat (Harris 1980). Are the species most likely to replace the biologically controlled weed more or less damaging than the original weed pest? Are they more or less costly to control? The answers to these questions have important implications for the long-run cost and thus the economic feasibility of a classical biological control possibility.

Augmentative biological control may, and inundative biological control most often does, involve direct cash outlay in addition to the possible opportunity costs of required changes in production practices. The market price of biological control materials for inundative use are determined by the value of the target weed's control (Bowers 1982). Thus, these materials are likely to be priced competitively with chemical herbicides. An advantage of host-specific materials is that the cost of applying them may be lower than for broad-spectrum materials. For instance, aerial applicators charge less to apply the spray formulation of fungal spore of *Colletotrichum gloeosporioides* (Penz.) Sacc. f. sp. *aeschynomene* (Melanconiales) than to apply 2,4,5-T ([2,4,5-trichlorophenoxy] acetic acid) for control of curly indigo in rice fields near soybeans. This is because they don't have to assume the risk of killing the beans (Kidwell 1984).

While direct cost advantages may be available from inundative use of mycoherbicides, this tactic also can require costly changes in production practices. For example, to

achieve adequate control of nutsedge by *Puccinia canaliculata* (Schw.) Lagh. (Uredinales), some farmers may have to alter their use of fungicides for crop protection (Phatak, cited in Kidwell 1984). By delaying fungicide application until the rust is well established, crop losses to other fungal diseases may increase. All user costs, both direct and indirect, need to be considered in the projection of a biological technique's economic feasibility.

#### *Relative Net Returns — The Ultimate Measure*

It is the comparison of benefits and costs of biological control with benefits and costs of current control that determines economic feasibility from the user's perspective. Economic feasibility is indicated when:

$$P[Q - f(DN)(1 - E_1)] - C_1 - g(V_1) < P[h(Q) - f(DN)(1 - E_2)] - C_2 - g(V_2)$$

where  $Q$  is the units of output (crop yield; animal carrying capacity; visitor days to parkland; volume of water flow; etc.) resulting from economic activity on uninfested land;  $P$  is the monetary value per unit of output; and  $f$  is the weed damage function, which reduces output as a function of  $D$ , the damage potential per individual weed, and  $N$ , the weed population density.  $E_1$  is the percent reduction in the weed population achieved by current control, and  $E_2$  is the percent reduction achieved by biological control.  $C_1$  and  $C_2$  represent the direct user costs of control by current and biocontrol methods, respectively.  $V_1$  and  $V_2$  are measures of the variability of current and biological control effects, respectively, and  $g$  is a function expressing how the user's attitude towards risk modifies the absolute value of benefits and costs. Finally,  $h$  is a function expressing how changes in current practices, required for effective biological control, modify output potential under uninfested conditions. This latter function represents the opportunity cost or benefit of changes in the output generating system.

Note that the comparison is made between current control and the biological alternative. The algebraic expression indicates that tradeoffs among cost, average effectiveness, and variability of effect of a weed control technique can be made without sacrificing degree of economic feasibility. For instance, a technique that has high user costs but low variability of effect may be as economically competitive with current control as one that has low costs and high variability.

Actual functional forms and absolute measures of the factors indicated in the algebraic equation most likely will not be available for use in quantifying economic consequences of a potential biological control technique at the point when research program decisions must be made. However, systematic, qualitative assessment of these factors and their interrelationships can be valuable in targeting for research particular weed-economic system-biocontrol agent combinations that are likely to yield economically feasible biological control techniques. Also, during experimental phases of a selected technique's development, the expected economic performance of the technique can be improved by attempting to optimize its application and increase the positive factors affecting economic feasibility (Taylor and Burt 1984).

If economic feasibility cannot be expected, even when a technique's management system has been optimized, it is doubtful that its target users will participate either in the technique's implementation or in the preservation of its potential benefits. If however, after factors affecting economic feasibility have been considered, a potential biological control technique is expected to be economically attractive to its users, it is useful to go beyond economic feasibility to examine the broader economic implications of the technique's implementation.

### **Beyond Economic Feasibility**

While an economically feasible biological control technique may be judged a profitable alternative by users, a variety of commercial or societal factors may preclude its availability or overall desirability.

#### *Potential for Commercialization*

The feasibility and cost of providing effective commercial biological control products are especially critical to the success potential for inundative biological control of weeds. Market potential needs to be assessed on the basis of the area over which the target weed problem exists and could be controlled by use of the marketed product. If the product cannot be employed by a sufficiently large number of users to make production profitable, it will not be commercialized. If only a small number of potential users exist, the product may not be made available even if those users are anxious to apply it. Other economic considerations for commercialization of biological control agents include research and development costs, need for capital investment, product cost, royalty and patent requirements, and the return on investment expected from production and sales (Bowers 1982).

#### *Public Intervention*

Public intervention in biological control may be necessary or desirable under certain circumstances. If a technique is judged economically feasible by users, is expected to yield high benefits, but does not have good potential for commercialization, the public sector may assume responsibility for helping users capitalize on expected benefits. In many cases, particularly for classical biological control techniques, the effective use of natural enemies cannot be achieved by individual users. Some form of regional organization is necessary to expedite the biological control approach. Because neither beneficial nor destructive impacts of a widely distributed biological control agent can be restricted to those who are willing to pay for it, government involvement in classical or, in some cases, augmentative biological control is a necessity (Tisdell *et al.* 1984). It is for these cases that the entire range of social benefits and costs needs to be assessed following an indication that a biological control possibility is likely to be judged acceptable and economically feasible by its principal beneficiaries.

#### *Societal Impacts*

A variety of individuals and groups other than the primary user group may be impacted by biological control of weeds. These include individuals who directly benefit from unsolicited weed control for which they, otherwise, would not be willing to pay, as well as individuals who are negatively affected because they view or utilize the weed as a beneficial species. Consumers of the output affected by the controlled weed may benefit more than the producers of the affected output. In the case of public biological control programs, the cost to the taxpayers for supporting weed control must be considered. Credible accounting of the full societal impacts of the biological control of weeds must include estimates of gains and losses to all affected groups. Leaving out a set of gainers or losers will lead to erroneous calculation of net societal impacts. External costs and benefits and market impacts need to be fully assessed to determine who gains, who loses, and by how much.

*Externalities.* Costs and benefits accruing to individuals external to the biological control user group are termed externalities. Externalities can be negative (external costs) or positive (external benefits). Conflicts of interest in the value of weeds give rise to

an important set of negative externalities (Andres 1981). A measure of willingness to pay to preserve the weed species, on the part of those who value its existence, is the relevant estimate of these external costs. Various methods are available to assess this willingness to pay (Yardas *et al.* 1982). Positive externalities may arise as biological control of the weed affects individuals who benefit from reduction in the population of a species not formerly recognized as a pest in their production system.

The net value of positive and negative externalities should be compared with direct net benefits enjoyed by the biological control user group. If the value of net benefits to gainers is larger than the value of negative externalities, society is said to be better off.

*Market impacts.* Estimating the full economic impacts of control of weeds in agricultural or other production systems further requires consideration of the potential response of the protected commodity's market. Reduced weed populations will increase yield and/or lower production costs for the affected commodity. If a large number of producers receive these benefits, increased levels of the commodity's supply may result. This stimulates a change in commodity prices. Production and consumption patterns respond, in turn, to the change in commodity price. The net effect of market interactions often will present large benefits to consumers of the affected commodity (Emerson and Plato 1978). These benefits can be of greater magnitude than the benefits accruing to producers. Bypassing estimation of the commodity price, supply, export, and other market changes arising from a major change in pest status will lead to misleading results with regard to the full economic impacts of the change (Kuchler *et al.* 1984).

*Benefit-cost analysis.* Benefit-cost analysis provides a useful framework for assessing total costs and benefits of biological control. Benefit-cost analysis should take into account money's future value and express the stream of private and public costs and benefits over time in a lump, present value measure (see chapter 5 of Reichelderfer *et al.* 1984). This assures benefits and costs are compared on a common basis.

## Conclusions

Selection of a biological control tactic with high probability of economic feasibility involves a search for the following characteristics: 1. The individuals or group responsible for application and/or maintenance of the potential biocontrol approach perceive the target weed problem as a serious one; 2. The economic activity impacted by the weed has high value; 3. Taxonomic and ecological characteristics of the weed and the biological control agent are such that efficacious control by the biological method is indicated — but, the value of damage per weed individual is not high; 4. The biological control agent's effect on the weed is neither slow nor highly variable; 5. There either is no current effective control available for the target weed, or current control is very costly; 6. Implementation of biological control does not require great expense by users, either in terms of cash outlay or the effect of a required change in production practices; and 7. The net economic returns to users of the biocontrol tactic are expected to equal or exceed those for alternative control.

The last of these characteristics is a function of the interaction of the six previous factors. Substitutability and complementarity among the first six factors listed can occur to make a biocontrol tactic possessing one or several undesirable characteristics a profitable alternative.

Economic feasibility of biological control of weeds can be expected under a range of conditions. It is most likely to be encountered for control of exotic weeds against

which herbicides are ineffective or excessively costly. The probability of economic feasibility also may be high in developing regions where the resources of subsistence farmers are insufficient to support capital-intensive production practices and/or labor availability limits productive capacity (Greathead and Waage 1983).

Once indication of economic feasibility is obtained, the selection process can further be refined by considering the broader socioeconomic consequences of biological control tactics' development and implementation. Comprehensive accounting for externalities and market impacts of implementation is a difficult task that need not be undertaken if the biocontrol tactic is not first determined to possess probable economic feasibility. For, if the tactic's users do not have incentives to adopt, utilize, and/or preserve the benefits of biological control, the tactic's broader impacts are not likely to be realized.

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