

ECONOMICS AND DECISION MAKING IN STORED-PRODUCT PEST MANAGEMENT

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Abstract

The economic concepts related to pest management in stored products are examined at three levels: on-farm storage, large-scale central stores, and national storage policy. Three models relevant to decision making at these various levels are discussed, including economic threshold models, investment models and risk models. The economic principles of control of storage pests before intake into large central stores versus post-intake control are discussed. The economic implications for pest management of national storage policy decisions, such as size of stock and centralisation, are considered. Finally, the need for information and decision support for managers is discussed, with suggestions on how decision support can be implemented.

Introduction

Decisions about stored-product pest management are made at various levels and over different time scales. The physical problems of pests under different storage conditions mean that different decisions will need to be made under a range of circumstances. Furthermore, the various decision-makers and their time frames impose a range of objectives, options and constraints which may result in different choices being appropriate under these conditions.

As a result there is no single economic model suitable for dealing with all stored-product protection decisions. Cost-benefit analyses have attempted to use relationships between pest numbers, grain quality/quantity and control measures to give some objective economic recommendations (Johnston and Price, 1986). Such models have shortcomings in dealing with risk, or the threat of pest attack, rather than its actual presence. Another general approach is decision analysis, which, since it includes how people use information to meet their objectives, is more a behavioral analysis than an accountancy exercise.

In this paper we discuss some of the general economic problems in stored-product protection decisions and describe some useful economic models. In conclusion, we consider the implications of these models as guides for biological research and extension services.

Participants in the grain storage system

Decision making is directed towards meeting individuals' objectives within their capabilities. It is, therefore, important to study the participants in the system first, and examine their situation, before assessing or evaluating their choices.

Three situations can be identified (Figure 1):

1. Self-sufficient farmers - who store and use grain on-farm without entering a market.
2. A domestic grain market - involving farmers and grain traders.
3. An international market - involving farmers, domestic and international traders

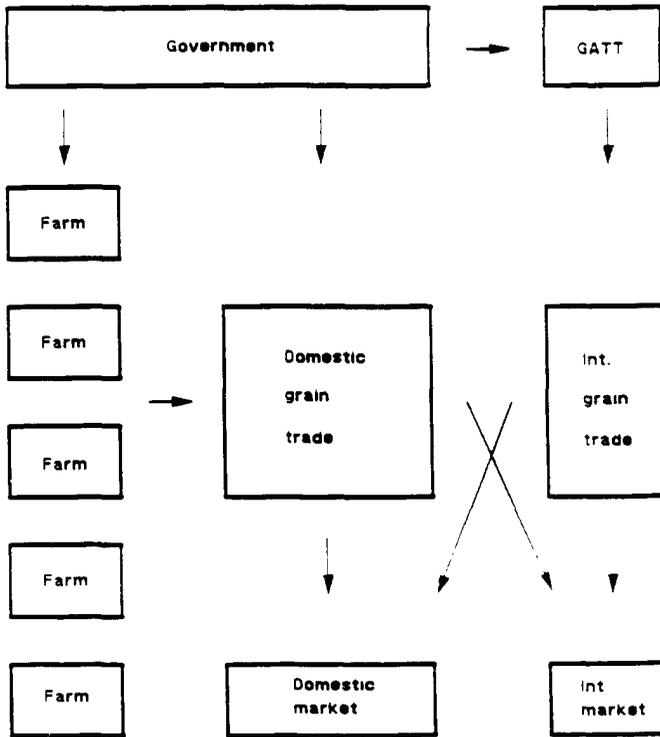


Figure 1. Participants in the grain storage system.

Government influence is always present and in the case of the international market, agreements such as the General Agreement on Tariffs and Trade may also affect economic conditions. Because of the strategic importance of grain, governments are likely at any time to change the economic conditions of the grain market, with possible consequences for decisions about pest problems. The recent price falls following the reduction in removal of the Iraqi market from international trade due to sanctions against grain sales to Iraq (eg 'Conflict in Gulf disrupts world grain markets', Independent newspaper, 3.9.90) highlight the uncertain impact of government controls on grain markets.

Within the context set by each particular situation the various players may have different objectives and the interactions between them may vary. Let us consider the three situations mentioned above.

Situation 1. Farmers, no market - quantity is the main aim, with quality a secondary consideration for human consumption. There are likely to be constraints of capital and expertise.

Situation 2. Farmers-grain trade, domestic only - quality is the main issue, affecting the amount of saleable grain. However, due to price inelasticity of demand (prices increase more

than quantity falls) (Kuchler and Duffy, 1984) farmers' implicitly benefit if pest infested grain (especially where the pests are pesticide resistant) is sent to the grain trade, causing post-harvest loss and higher prices. This contrasts with preharvest pests which affect individual farmers, so each farmer has an incentive to control such pests. The incentive for pest control on-farm will be increased if there is a long period of on-farm storage first, for instance if prices rise some time after harvest, but if the price is fixed all year there is no incentive to store when you can sell grain immediately.

Situation 3. International trade - quality is the main issue. The position of the domestic market within the larger international market means that the farmer has an implicit incentive to control pests and cooperate with the grain trade to maintain a position in the foreign market and so keep prices high. However, foreign market access is a common property resource and there may be some cheating by individual farmers hoping to cut costs by taking fewer pest control measures. Government may need to encourage or regulate farmers and the grain trade to help maintain market standards for the benefit of all domestic producers.

Models for decision making

Figure 2 illustrates some of the decisions made by grain store managers over time, from planning decisions, made (say) every 10 years or more, down to weekly decisions. Clearly the options available for each of these decision periods is very different, as is the most appropriate decision model to use in making choices. Let us start with the shortest time period and the threshold model.

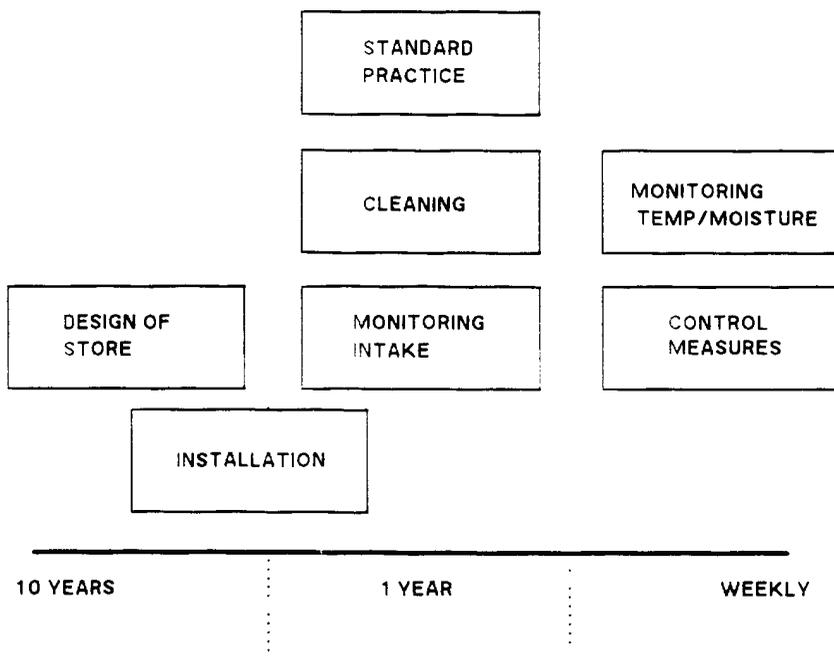
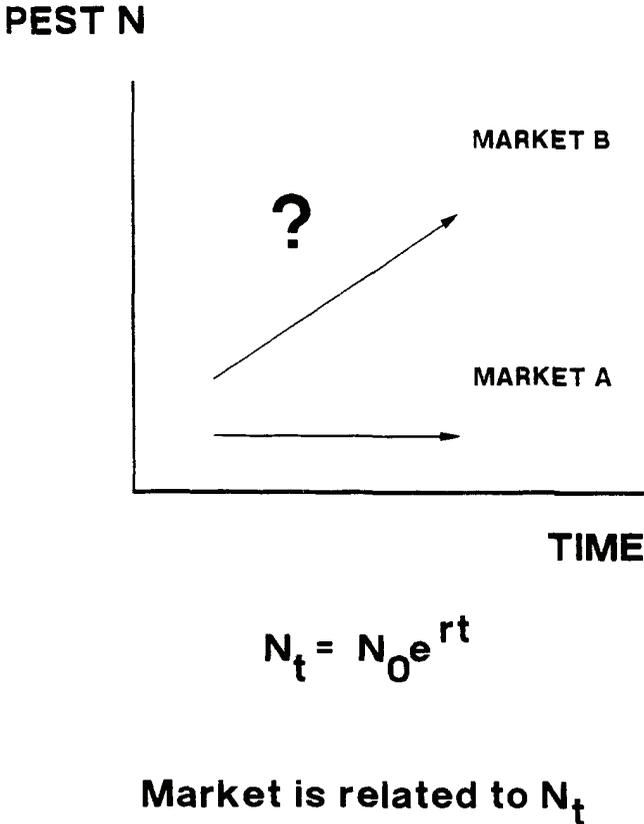


Figure 2. Time profile for some example storage pest control decisions.

Short term decisions - threshold model

The problem here is how to get from the present condition to an acceptable condition at the point of sale. A biological model is necessary to predict pest increase under various environmental and management conditions. Pest population growth in stored products can be expressed in simple terms using the basic exponential model, $N_t = N_0 e^{rt}$. Market (and price) is directly related to N_t , where t is the time to expected sale (Figure 3).



Market is related to N_t

Figure 3. In the short term, at low densities, pests will increase exponentially.

In many instances management involves meeting a specific market tolerance for pests in grain, generally at a very low level. If the manager expects pests to be above this threshold at the time of sale, causing a considerable price reduction, four categories of response can be considered (Figure 4). In this case, the economic choice involves identifying the least cost combination of these options. Thus, the manager needs to predict what will happen given each control or management option being considered and compare the outcomes and costs.

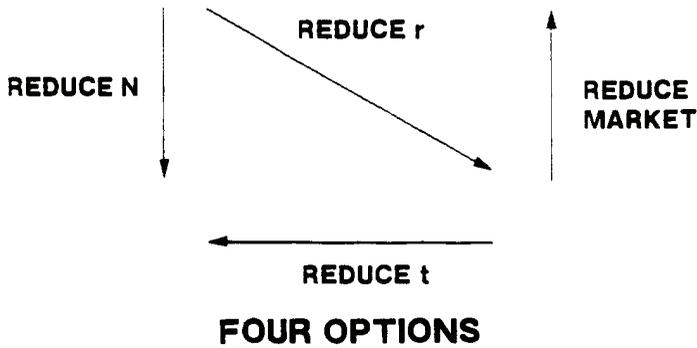


Figure 4. Four general options for pest control.

The simple exponential model is probably an adequate predictive model at low pest levels, which is generally where difficult decisions need to be made. With reasonable levels of management pest populations are not likely to get near the carrying capacity, and inter- or intraspecific competition is an unnecessary consideration at low levels. At higher population levels, the need for control is likely to be so clear that it does not pose a difficult decision problem (though it might be a difficult practical and financial problem), or the management may be so poor as to be incapable of using even a simple decision model.

In biological terms models of quality and physical loss in stored grain are very simple, since the area of interest is at relatively low densities in a relatively stable environment with few outside influences (ie natural enemies, etc). Damage and control relationships are also relatively straightforward since the product is no longer growing, and in store it is protected from other causes of variability. Prices are often fixed as well, reducing uncertainty further. On the other hand, a major difference to preharvest pest control models (Mumford and Norton, 1984), and a feature which makes stored grain pest control more complex, is that the timescale is not fixed (in field crops, you can define harvest reasonably well). The main factors to be considered in a threshold model are listed in Table 1.

Table 1. Decision components for threshold model.

pest species, number	number/tonne
monitoring cost	£/tonne
monitoring accuracy	number/tonne
temperature	C
moisture	%
pest growth rate	/time
pest tolerance	number/tonne
residue tolerance	ppm
control capacity	
admix	tonne/day/£
fumigate	tonne/day/£
clean	tonne/day/£
control atmosphere	tonne/day/£
cool	C/tonne/day/£
dry	%/tonne/day/£
alternative market prices	£/tonne

In some cases, such as with the grain weevil, *Sitophilus granarius*, the temperature and moisture conditions under which the pest can increase overlap the market tolerances for temperature and moisture content (Figure 5) (Howe, 1965). There will be economic pressure on store managers to allow stored grain to have as high a temperature and moisture content as possible, while still meeting market requirements. Under these conditions it is essential that managers have access to good information about the growth potential of the pests so that they can accurately predict the likelihood of exceeding pest tolerance levels.

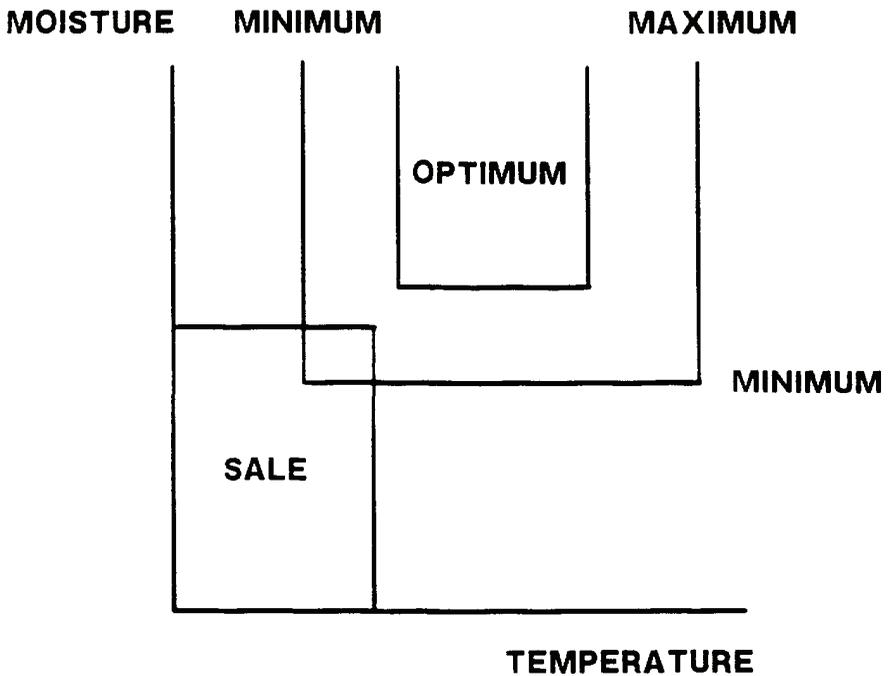


Figure 5. In some cases conditions for suboptimal pest increase overlap conditions that are within market tolerances.

The time it takes to achieve control for each possible option is another factor that must be considered (Figure 6). For instance cooling and drying take a while to work, during which time insects still increase. This may have implications for the level of loss or the cost of control. It may also preclude the use of a threshold model, if it is not possible to monitor early enough to take any action (third case in Figure 6). In this case a risk model is more appropriate.

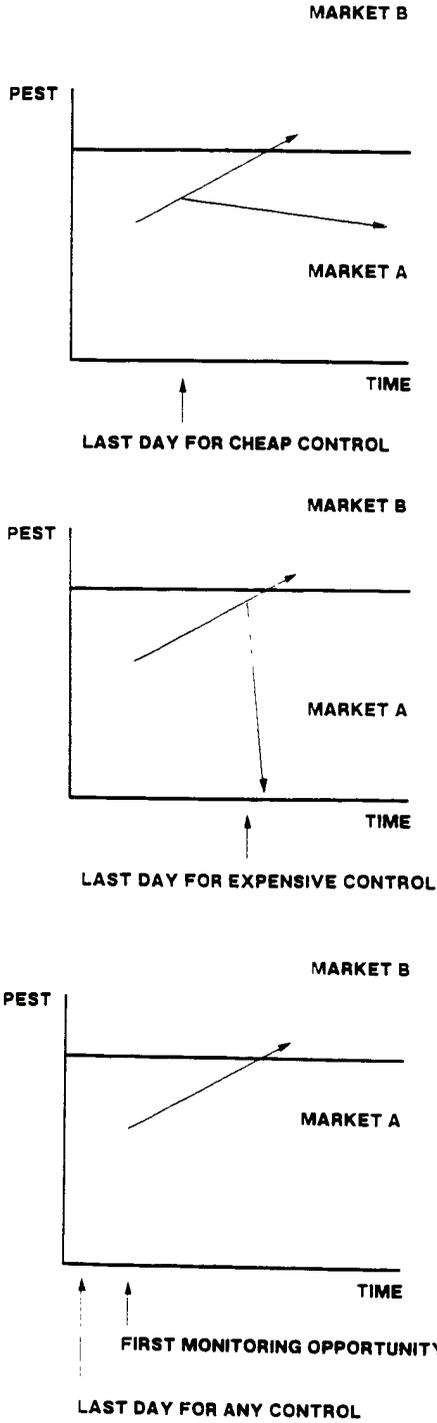


Figure 6. Different control options have different planning horizons.

Short term decisions - risk model

A particular problem is that sampling can in some cases be more difficult than in field crops (it is hard enough to sample rice pests in the field, but it is nearly impossible to get into the centre of a bagged stack). The sampling problem makes stored product decision making more like some field disease action thresholds than field insect thresholds. Pathologists often base action thresholds on the growth rate potential without an accurate estimate of the initial inoculum level. With high potential growth control is against the risk of damage rather than known actual presence (since the latter is difficult, hence expensive, to monitor).

Where decision makers are faced with uncertainty, related to sampling error or lack of sampling, risk models, based on the probability of pest attack, are more appropriate decision aids. Using a simple biological model, such as the exponential model discussed earlier, it is possible to work backwards from population levels at which the market price changes to the population that would exist at the present time if it was going to reach that point under given temperature and moisture conditions. There will, therefore, be a target N at time t . We will also be able to estimate the maximum r for the worst pest (the pest with the greatest potential for increase) at the current temperature/moisture. Given r and some estimate of the time until sale, it is possible to estimate the present population N that would give rise to the target N_t . Action should be taken if the probability of the present pest level being higher than the backtracked level is high (that is, too risky). This is a subjective estimate, dependent on the manager's attitude to risk. A 10% probability may be too high for a risk averse manager, while more risk tolerant managers may accept higher probabilities without taking action.

The risk of pest attack may be assessed on the basis of estimates depending on: the type of store; the history of store/grain source, the management capability; previous control performance; the target market.

Another element of risk is that imposed by sampling error. Figure 7 shows how such error can reduce the time for action by forcing a risk averse manager to respond to the worst possible threat rather than to the real pest population level.

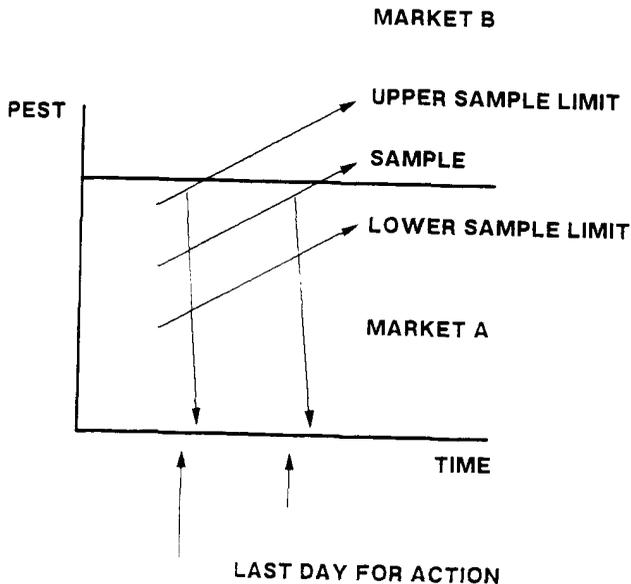


Figure 7. Sampling error introduces an element of risk which may cause managers to take pest control actions earlier than they otherwise would.

Long term decisions -investment model

For long term decisions, such as the investment in new storage facilities and plant a manager must consider the long term likelihood of pest intake and growth within the stores. It is also necessary to consider discount rates on future benefits and the depreciation periods for the capital investment. Managers must compare any investment opportunity to the best alternative investment, leaving out costs that could be attributed to other requirements, such as equipment needed to meet contract moisture levels.

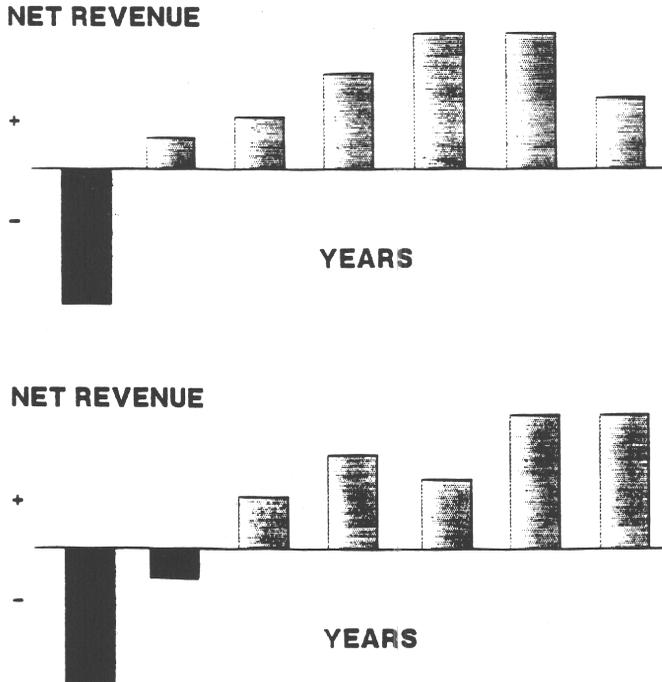


Figure 8. Investment decisions must be considered on both the magnitude of return and the timescale over which returns are realised.

Another long term consideration for storage policy concerns the choice of on-farm or centralised storage (Love et al., 1983, Johnston, 1985). Apart from the costs, estimates must be made of the relative risk of loss under these two policies. Given the strategic value of grain stores risk reduction is probably a higher objective than simple revenue maximisation or cost savings. Risk could be assessed objectively by surveys of stores, and subjectively by surveys of farmers and store managers. The following risks would need to be determined: pest intake into various types of stores; ability to control pests once in the stores; the development of pesticide resistance under each type of store management; the pesticide residue levels that would be left in grain from each store type.

Conclusions

Better stored-product protection requires three types of improvement from research and extension: low cost, effective control options; information on pests and controls; and information processing.

There will always be a demand for low cost, effective control options. However, it seems unlikely that major breakthroughs in control technology or price are likely. There will probably continue to be some incremental improvement in control performance through more efficient management and technology in some areas, such as grain cooling, drying, cleaning etc. Countering this, however, there could soon be fewer low cost options if residue requirements drive pesticides out of the stored-product market. This would put store managers under greater economic pressure, and could require them to make more complicated pest management decisions.

McFarlane (1989) has extensively discussed research needs in stored-product protection, particularly for developing countries. In general, we feel that there are three particular areas in which better information is needed for stored-product protection decisions:

- low cost, effective sampling of pest numbers (at low density)
- low cost, effective sampling for residues
- suboptimal growth rates for pests that can increase within market tolerance levels of temperature and moisture

It should be noted, however, that improved sampling techniques could prove to be a two-edged sword, alternatively benefitting buyers or sellers of grain, depending on the state of the market.

There will also be a demand for help with information processing or decision support (for instance, using expert systems or interpretive sampling devices). Without good information a decision maker may as well just make a good guess or adopt a standard operating procedure, but once you have access to good information (say from IR monitoring, trapping, etc) then you need to be able to use it sensibly and quickly. For large scale managers this may best be implemented using computerised expert systems (Wilkin et al., 1990). For small scale managers or farmers the rules in such computer systems would need to be simplified and transferred to wallcharts or booklets.

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PRISE DE DECISION DANS LA GESTION ECONOMIQUE DES RAVAGEURS DES PRODUITS STOCKES

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Résumé

Nous examinons les concepts économiques en rapport avec la gestion des ravageurs des produits stockés sur trois niveaux : le stockage à la ferme, ; le stockage en magasin central à grande échelle ; la politique de stockage nationale. Nous discutons de trois schémas relevant de la prise de décision à ces trois niveaux, y compris ceux du seuil économique, de l'investissement et du risque. Nous illustrons les principes économiques régissant le contrôle des produits avant et après leur entrée dans les vastes magasins centraux. Nous discutons de l'implication économique des décisions concernant la politique de lutte contre les ravageurs des stocks nationaux, comme la taille des stocks et leur centralisation. Nous discutons aussi du besoin d'information et d'aide à la décision des dirigeants à tous les niveaux et nous apportons des suggestions sur la façon de concevoir cette aide à la décision.