Modeling farmers' decisions: a comparison between HDM and CART for oats-vetch adoption in the Ethiopian Highlands

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Modellierung von bäuerlichen Entscheidungen: ein Vergleich zwischen HDM und CART anhand von Hafer-Wicke-Anbau im Äthiopischen Hochland

1. Introduction

The rate of adoption of new or improved agricultural technologies in Third World countries has not been satisfying, as neither the size nor the distribution of the benefit have matched the expectations of the implementing agencies and national governments. This result is generally attributed to the neglect of the "human element" in farming systems in the traditional research approaches (Norman and Baker, 1986; Walker et al., 1995). Researchers increasingly realized that the effect of a new technology largely depends solely on its technical importance, and the "human", "social" and "technological" factors need to be taken into consideration, if the full potential of a technology is to be exploited.

As direct and creative farmer participation has been elusive, the necessity for a two-way linkage between different participants in the research process was recognized.

New approaches seek to thoroughly understand the farmers' situation and perspective and to integrate these factors into agricultural research (Chambers, 1994). Their roots are found in the recognition that a farmer's decision depends on, and is influenced by, his own knowledge and perception of a technology, rather than the researcher's knowledge of the technology (Gläwes et al., 1984).

The underlying assumption is that the decision making process exists as expert on how they make the choices they make.

With the focus on the farmer whose adoption or rejection of the new technology can make or break a project, the researcher needs to know: (1) what decision the farmer will make, (2) what alternative he/she is considering, and (3) why he/she chooses a particular outcome (Gläwes, 1982).

The present study aims to elucidate the criteria influencing the adoption decision of an improved feed for crossbred

Zusammenfassung


Schlüsselwörter: Entscheidungsmodellierung, HDM, CART, Äthiopien, Hafer-Wicke.

Summary

Farmers' decision to adopt an improved feed (oats-vetch) is modeled with the help of two methods: hierarchical decision trees (HDM) and classification and regression trees (CART). The models are used to help explain why oats-vetch was not adopted by farmers in the Ethiopian highlands to the anticipated extent, and can be used to provide a guide for future extension efforts. The strengths and weaknesses of the two methods are compared. Both are found useful for compiling information about farmers' opinions, attitudes and actions in a meaningful manner.

Key words: adoption decision, HDM, CART, Ethiopia, oats-vetch.

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cows in the Sela area of the Ethiopian highland are intercropped oats-vetch. The study was made in the context of a development project by the Ethiopian Ministry of Agriculture (MoA) and the Finnish International Development Aid (FINNIDA) (MoA/FINNIDA, 1986). The project, which was implemented between 1987 and 1991, distributed crossbred cows against credit to farmers, to enable them to raise milk production both for household consumption and as a source of cash income. As crossbred cows require both quantitatively and qualitatively better feed than local zebu cows, improved feed production was promoted. The recommendations included intercropping oats and vetch; oats is already well known by the farmers in the area, and intercropping the two species raises both the crude protein content and the dry matter yield, without using supplementary crop land which is scarce.

The models presented hereafter examine reasons why farmers will or will not plant vetch, and if they do, whether or not they will intercrop it with oats, as was recommended by the MoA and FINNIDA. The decision criteria are assembled into decision models using two methods: Hierarchical Decision Models (HDM) as well as Classification and Regression Trees (CART). The juxtaposition of the 'manual' model and the computerized analysis should allow the comparison of the strengths and weaknesses of the two analytical tools. Further details of the research reported herein are presented in Darshofier (1997).

2. The methods

2.1 Hierarchical Decision Models

Christina Gladwin (1976) developed a method called hierarchical decision modeling (HDM) to model the way people make two-life decisions. Its distinctive features are: (1) a reliance on ethnographic fieldwork techniques to elicit decision criteria, and (2) combining these criteria in the form an inverted tree which is read like a flow-chart.

The form of a decision tree is simple: the possible outcome of the decision to be modeled is formulated at the top of the tree for easy reference. Each decision criterion forms a node of the tree. The decision variables or criteria have discrete values (Gladwin, 1975). These discrete criteria can be either rejected or accepted. After a number of criteria have been passed, the decision outcome is reached at the end of a path of the tree. These outcomes are of the general form: 'do A', 'do not do A'. A decision tree is thus a sequence of discrete decision criteria, all of which have to be passed along a path to a particular outcome or choice (Gladwin, 1989).

2.2 Classification and Regression Trees

The authors of CART and developers of its computational algorithm are the statisticians Leo Breiman, Jerome Friedman, Richard Olshen and Charles Stone (1984). Their aim was to develop an easy to use statistical package for tree-structured nonparametric data analysis to tackle classification problems.

The classification trees are also drawn in the form of an inverted tree and are read as like a flow-chart. To decide how to split a node, the CART software examines all possible splits for all variables included in the analysis, and ranks them on a goodness-of-split criterion. The most commonly used criterion is how well the splitting rule separates the classes contained in the parent node, i.e. decreases class impurity.

The CART output is thus composed of several elements: the optimal tree, with detailed information for each node, such as the variable on which the node was split, the number of cases going right and left, and the improvement in class purity. Additional information on variables are also provided, such as possible competitor variables on which the node could also have been split but with a less optimal result and surrogate variables whose split would have divided the data similarly and which can be used as alternative in case of missing data.

2.3 Data collection

Following the method set forth by Franzel (1984), the data for this study were collected in two stages: first all the decision criteria were elicited from key informants and, in a second stage, the criteria were compiled into a formal questionnaire and data gathered from 50 randomly selected farmers, providing the data used in the models.

The key informants for the interviews held in the first stage were knowledgeable enumerators, farmers and MoA officials. These were instrumental in acquiring a better understanding of influencing factors and the problems that farmers may face with vetch. These first stage interviews took the form of informal conversations, without pre-formulated questions. During the interviews care was taken to follow ethnographic guidelines (Spradley, 1979; Atte-
LANDER, 1993). This first stage is an iteration between eliciting criteria, building draft decision trees to organize the criteria, eliciting further criteria and modifying the draft tree. Once the draft decision tree seemed reasonably complete, the questions underlying the decision criteria were written up and a formal questionnaire designed.

In the second stage of data collection, 50 randomly sampled farmers who had participated in the MoA/FU/NIDDA project were interviewed. The data collected during this formal survey were then used to build the final decision model. For the CART analysis all questions were entered for the software to be able to select the most appropriate splitting variables.

3. Decision models of oats-vetch

3.1 HDM of oats-vetch

Figure 1 starts with reasons why some farmers have never planted vetch, and will therefore be excluded from the further model, since they have no direct experience with the crop. It is better to illicit criteria from a farmer who has actually made a decision, rather than one who has no firsthand knowledge, as his/her answers will likely be hypothetical. Of the 50 interviewed farmers, eight have never planted vetch, as they never got seeds, or do not think vetch will grow in their area, or do not have enough land to plant vetch. This last group of two farmers, one of whom has never planted, and the other having planted vetch once, shows a reluctance of the farmers to intercrop vetch at the first trial. Also, "lack of land" is a surprising argument as if they would intercrop oats and vetch, as recommended, it would not require any additional land, making it a practice particularly relevant to those farmers who do not have enough crop land. The reluctance to intercrop might partly be due to the fact that intercropping is not a traditional practice in the area. The remaining farmers have all planned vetch at least once, and the criteria influencing their choice whether or not to plant it this year can be analyzed. A first group of seven farmers exits the decision tree, as they are not satisfied with the performance of vetch, when they first grew it. This poor performance might be due to cool temperatures at the higher altitudes, or a lack of water at the lower altitudes, depending on the rainfall in the year when the farmer first planted the crop.

The decision tree then subdivides the farmers in two altitude sub-locations: those living at an altitude ranging from 2500 m to 2700 m and those living at an altitude range between 2700 m and 3000 m. Above the 2700 m range, frosts are likely to occur between November and December, the period during which vetch flowers. These occasional eight time frosts seem to hinder the seed production of vetch.

In the view of the farmers experts the imputed seed production is not a problem, as the oats-vetch mixture is meant to be harvested and fed green. But no farmers this is a major factor. On the one hand, a number of farmers remarked that planting a crop which does not produce seeds is useless. On the other hand, farmers are well aware that if they cannot produce their own seeds, they entirely depend on the MoA for the supply of vetch seeds, as these are too available on the market. Since the MoA does not have sufficient vetch seed for distribution to all interested farmers everywhere, it is a constraining factor. In other words, a farmer who is not able to produce his own seed, will most likely not be able to plant it again the following year. This is reflected in the answer of 13 farmers, who, despite the fact that they are interested in growing the crop, "will not plant vetch this year, due to a lack of seeds".

In figure 1 most farmers are satisfied with the results of intercropping and will plant vetch this year if they receive seeds from the MoA or if they have left-over seeds from a previous year. As seed production is not an option due to the risk of frost, farmers in this area are more likely to intercrop. The two farmers who are not satisfied with intercropping oats and vetch, could still plant vetch as a sole crop, but the farmer who would like to do so is prevented by his lack of seeds.

Figure 2 presents the decision process of farmers living at lower altitude, and who can secure their own supply of seeds if they plant at least part of the vetch as a sole crop. Two problems appear at that level: first a palatability problem, as farmers say that their cows do not like vetch. The other problem is the uncertainty of the 'right' planting time for intercropped oats and vetch.

The MoA recommendation is to intercrop and plant towards the end of the rainy season, i.e. in September. To farmers vetch (Vicia sativa) is a novel crop with which they have no experience, but due to the illensness of vetch seeds with the enes of rough pea (Lathyrus sativus), a crop most of the farmers plant, they conclude that these two crops will have similar characteristics. This link in the farmers belief is shown in the fact that they use the same oromo word ("gana") for both plants, differentiating them only through specifying whether it is "ganaa" (rough pea) or "ganaaf" (oats).
(have you ever planted; never planted)
(will plant vetch this year; will not plant)
[50 farmers]

Did you ever get vetch seeds from the MoA?
Yes [47]  No [3]

Do you think vetch will grow in your area?
Yes [43]  No [4]

Do you have enough land to plant vetch?
Yes [41]  No [2]

When you grew vetch, were you satisfied with the results?
Yes [34]  No [7]

Will vetch produce seeds in your area?
Yes [21]  No [13]

Go to Tree 2
Part 2
[21 farmers]

When you intercropped oats and vetch, did they grow well together?

Do you now have seeds from the MoA?

Are you interested in growing vetch alone?
Yes [1]  No [1]

Will plant and intercrop this year [5 farmers]  Will not plant this year due to lack of seeds [6 farmers]

Do you still have seeds from the MoA?
Yes [1]

Will plant this year due to lack of seeds [1 farmer]

OUTCOME
Will not plant:
- no seeds: 10 farmers
- no interest: 8 farmers
- no land: 2 farmers
- vetch won’t grow: 4 farmers
Will plant:
- intercropped: 5 farmers

Never planted, never got seeds [3 farmers]
Never planted, fed seeds to the cow [4 farmers]
Will not plant due to lack of land [2 farmers]
Have grown, but no further interest [7 farmers]
Farmers who have grown vetch, are satisfied with the results, and live in an area where vetch will produce seeds (21 farmers)

Does your cow like vetch?

Yes [16]

No [5]

Do you think oats will grow in September?

Yes [1]

No [9]

Do you think vetch will grow in April-June?

Yes [3]

No [5]

Can you get seeds from the MoA?

Yes [2]

No [4]

Will plant both intercropped and alone [8 farmers]

Do you want to plant some vetch alone for seeds?

Yes [8]

No [4]

Can you get seeds from the MoA?

Yes [1]

No [6]

Will plant all intercropped [1 farmer]

Will not plant this year due to lack of seeds [3 farmers]

OUTCOME: Will not plant:
- no interest: 4 farmers
- no seeds: 6 farmers
- all: 6 farmers

Will plant:
- as sole crop: 4 farmers
- intercropped: 1 farmer

Will plant vetch solely to sell the seeds to the MoA [1 farmer]

Will not plant due to lack of interest [4 farmers]
3.2 CART of oats-vetch

The tree in Figure 3 shows the CART tree, classifying farmers in five classes: (0) farmers who have never grown vetch, (1) whether the farmer will plant vetch as a sole crop or (2) intercrop it, or (3) do both, and (4) those farmers who will not plant vetch this year. These categories are similar those of the HDM tree in Figure 1 and Figure 2.

The first question selects those farmers who have never grown vetch, as these were not asked the remaining questions due to their lack of personal experience with the crop. Those who have grown vetch at least once are then divided between the area above 2700 m and those below. The next question for farmers in front-zone areas concerns the issue whether or not they can get vetch seeds from the MoA. Of the seven farmers who can get seeds from the MoA and who are therefore classified as farmers who will intercrop, only five will plant and intercrop, and two are misclassified as they will not plant vetch.

The farmers located in the lower area, where vetch produces seeds are asked whether or not they think that oats and vetch grow well together, a question addressing the problem of optimal planting time. Those who do not think intercropping advisable are classified as farmers who will not plant. Of the 12 farmers in this terminal node, nine will not plant vetch at all, and three are misclassified, as they will plant it as a sole crop. The farmers who think that intercropping oats and vetch is not a problem, are asked if their cross-bred cow likes the mixture of green oats and vetch. Farmers say that their cows do not like it, of which one will not plant vetch at all, and the other will plant some oats, and some intercropped. Of the 10 farmers whose crossbred cows like the oats-vetch mixture, six farmers will plant vetch both as a sole crop and intercropped with oats, one will intercrop all of its vetch and three will not plant any vetch this year.

The consistence of the CART tree allows the decisive factors to become more apparent than in a larger tree with more details. On the other hand, the price for such a succinct tree is misclassification: of the 50 interviewed farmers, 10 are misclassified. Only two terminal nodes are 'pure': those farmers who have never grown vetch, and those who will not plant due to lack of seeds from the MoA. The four remaining terminal nodes all have some 'impurity', i.e. misclassified cases. For CART splitting these nodes further does not sufficiently reduce node impurity to be worth the higher complexity, i.e. the penalty imposed per additional terminal node. The 'right' size is a trade-off between misclassified
50 farmers interviewed

Have you ever grown vetch?

Yes [42]  

No [8]

Does the farmer live above 2500 m?

Yes [18]  

No [24]

Can you get vetch seeds from the MoA?

Yes [7]  

No, don’t know [11]

Do oats and vetch grow well together?

Yes [12]  

No [12]

Does your crossbred cow like the oats-vetch mixture?

Yes [10]  

No [2]

Class: 0

'Will not plant'  
Cases: 11  
Misclassified: 0

Class: 1

'Will intercrop'  
Cases: 7  
Misclassified: 2  
(2 cases class 0)

Class: 2

'Will plant alone'  
Cases: 2  
Misclassified: 1  
(1 case class 0)

Class: 3

'Will intercrop and plant alone'  
Cases: 10  
Misclassified: 4  
(3 cases class 0, 1 case class 1)

Class: 4

'Never planted'  
Cases: 8  
Misclassified: 0

Misclassification by class:

<table>
<thead>
<tr>
<th>Class</th>
<th>N</th>
<th>N misclassified</th>
</tr>
</thead>
<tbody>
<tr>
<td>0: Will not plant this year</td>
<td>26</td>
<td>6</td>
</tr>
<tr>
<td>1: Will intercrop oats and vetch</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>2: Will only plant vetch alone</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>3: Will both intercrop and plant alone</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>4: Will not plant: have never planted</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
<td>10</td>
</tr>
</tbody>
</table>
cases and tree size, as in virtually all applied statistics parsi-
mony is considered a desirable feature in a model (Stein-
berg and Colla, 1995).

3.3 Summary of influencing factors
Overall the main problem seems to be seed availability, as the Ministry of Agriculture does not have sufficient seed to supply all interested farmers. Therefore farmers have to secure their own seed which is only possible if the farmer lives in the lower "triangle area" and if he does not intercrop all of his vetch since when intercropped it will be harvested at the flowering stage. The seed supplied is therefore one rea-
son some farmer are reluctant to intercrop oats and vetch, but the reluctance might also be due to the fact that inter-
cropping is not a traditional practice in the area.

Another factor that became clear in the course of the interviews is that the similarity between the seeds of rough pea and of the vetch mslides the farmers to assume the two crops have similar characteristics concerning planting time. Linking the two crops is also problematic as rough pea is toxic when consumed in larger quantities, so that farmers might erroneously think that vetch could be toxic for their cows. This fear of toxicity might be one reason some farmers do not put too much energy in getting their cow used to this novel feed and complain of palatability problems.

Most of the factors inhibiting the wider adoption of oats-
vetch in the Selale area can be addressed through extension and demonstrations at field-days by the MNA. To reinforce the extension message, seeds need to be made available to farmers who are already interested and who can therefore serve as demonstration farmers to their neighbors.

4. Evaluation of HDM and CART
Although simple in appearance, the above described deci-
sion trees of a feed crop in the Ethiopian highlands, have shown that decision models are useful for assembling infor-
mation on farmers' opinions and perceptions in a system-
atic way so as to show the logic behind farmers' decisions. This is a strong advantage compared to the more classical statistical analysis which will focus mainly on the frequency of a factor that is mentioned by interviewed farmers without revealing the chain of thought of the farmers and the inter-
connectedness of the factors.

The two methods have their respective strengths and weaknesses, which will be displayed in different research set-
tings. One difference lies in the influence of the sample size. In many agricultural data collection settings, the number of farmers interviewed rarely exceed 100 or 200, due to the high demands in personnel and time necessary to interview each farmer, as well as the limited funds and time available for most data collection. This relatively small sample size, particularly its lower range, is not a problem for analysis through HDM, if the number of variables on which the data are collected is relatively limited. CART, on the other hand, will analyze several thousand cases and a large num-
ber of variables effortlessly. The larger the number of cases, the more appropriate CART is likely to be, because patterns are easier to distinguish with larger sample sizes.

HDM has limitations concerning the type of information which can be included in the model: the decision to be modeled needs to be narrowly framed, i.e. have only a few possible outcomes, and the alternatives and decision crite-
ria must be discrete. Where a wide array of choices is avail-
able, and most farmers select several different alternatives, the analysis becomes muddled with multiple nodes and branches. This makes the analysis excessively complex, and the interpretation difficult or impossible. Should the decision variable be continuous (e.g. area planted with oats-vetch), it can only be modeled if, in the farmers' view, there is a logical reason allowing interval formation, thereby making the variable discrete.

In most decision models this should not be a problem. But in certain circumstances it might be desirable to widen the data collected to variables such as household size, cattle number or hectare land cultivated, and analyze it together with the ethnographic data. CART will be able to find the most appropriate grouping and therefore split between the groups, even with continuous variables, finding the cut-off value through the same method of reduction in node impurity.

Another difference between HDM and CART is the size of the resulting tree. Trees built by CART will in almost all cases be more compact than trees built through HDM. This also means that the amount of information contained in a CART tree will be lower compared to a HDM tree on the same topic. For example, the HDM tree in Figure 2 speci-

ies why the farmer will not grow vetch this year (e.g. 'lack of interest'), whereas in the CART tree Figure 3, the out-

come is simply labeled as 'will not plant'. Which one is preferable will depend on the context and the main aim of the study. If the study aims at an overview of the important
5. Conclusion

Decision trees allow to structure and present information gathered from farmers through ethnographic interviews in a logical and easily understood form. Some of the weaknesses and strengths of the two methods used in this research have been illustrated. Still, with both HDM and CART, the analyst needs a "feel" for the data in order to reach a comprehensive assessment of the variables under consideration. Therefore, with both methods, as with all data analysis, yielding good and honest results is a "mixture of art and science, involving considerable subjective judgment" (BREIMAN et al., 1984).

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