The crop rotation index explained

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Introduction

In the following we explain how we have arrived at the indicator designated as "crop rotation index". It is a score that is calculated on the basis of agricultural data pertaining to one particular agricultural field. The purpose of this, is to have an indicator for evaluating the choices a farmer is making as far as the type of crops is concerned which he grows on his field. This indicator was in the first place developed for use within the Netherlands.

Background

The development of the crop rotation index should be seen against the background of the changing involvement of the Dutch government and of the European Union (EU) in agriculture. For many years, the Common Agricultural Policy (CAP) - as implemented by the EU in cooperation with the Dutch government – used to reward individual farmers with subsidies purely for the amount of agricultural product they produced. With the growing realisation in Dutch society in the past 10-15 years or so, that farmers are also guardians of nature, the landscape and the environment at large, it is generally felt that new ways are needed for rewarding individual farmers. The idea is therefore that the CAP should be modified and that rewards should be integrated into it for the services they provide to society – i.e. ecosystem services such as soil and water conservation and biodiversity-friendly farming.

All Dutch farmers already stick to a discipline called "crop rotation" with the following aims:

- to prevent disease in their crops (phytosanitary)
- to allow the soil to recover from demanding crops (soil fertility)
- to prevent soil erosion.

In the case of the crop rotation index, the intention was indeed to develop an indicator for rewarding the individual farmers for their discipline, or in other words for taking good care of the soils. Besides the conservation of the soil resources - with the life forms present in it – we considered that in principle such good care also impacts:

- the surface water and groundwater resources in the area; and
- the life forms living above the soil surface.

It would have been almost ideal to base the indicator on the analysis results of regularly taken soil samples. However, this would mean setting up a system that involves high running costs. In the Netherlands, soil samples are taken at representative points already on a regular basis and it would be more logical to track trends in the analysis results in an indirect way, e.g. by relating them with external influences on the soil.

We believe management practices are the most important external influences on the soil and our plan is to investigate this further in the near future to support our approach. For the initial stage, we decided to make use of relevant data which are easily available already. The data we had in mind in particular are those which every farmer declares himself / herself every year to the government service RVO

– part of the Dutch Ministry of Economic Affairs. This declaration is called "Combined Declaration" and includes main crop type during the calendar year for every parcel in use by the farmer. Data from the "Combined Declaration" are made available in a strictly anonymised form to researchers, i.e. per land parcel.

Starting points

It was considered that a suitable crop rotation would favour:

- the chemical state of the soil
- the physical state of the soil
- the biological and phytosanitary state of the soil
- the biodiversity above the soil surface.

Based on the above, we contemplated which management characteristics surrounding an agricultural field could easily be quantified from the RVO data in the form of scores. For the "Combined Declaration". RVO distinguishes about 430 different crops. We felt that it would not make sense to distinguish so many crops. We rather grouped crops into 10 different categories:

- Cereals, abbreviated with C: wheat, barley, rye, oats, buckwheat etc.
- C4 crops, abbreviated with M: maize, millet and sorghum
- Potatoes, abbreviated with P
- Other root crops, abbreviated with R: beetroots, sugar beets, onions, carrots, garlic, chicory roots, parsnip, topinambur, flower bulbs etc.
- Leguminous crops, abbreviated with L: beans, peas, lupine, clover, alfalfa etc.
- Grasses, abbreviated with G
- Cabbages, abbreviated with K
- Other crops, abbreviated with O
- Fallow without cover crop, abbreviated with F
- Perennial crops, abbreviated with T.

We came to the following list of quantifiable management characteristics:

1. number of unique categories included in the rotation
2. number of times the most often planted category occurs in the rotation
3. number of times the least often planted category occurs in the rotation
4. number of times that green manure crops are included in the rotation
5. minimum spacing observed over the years for any non-grass category
6. maximum number of times a non-grass category is grown in a row
7. minimum number of years observed between 2 potato crops
8. number of years with root crops.

More on the rationale behind the above characteristics:

- the more categories are included, the more diversity is realised - positive
- the oftener a particular category is planted, the less diversity is realised - negative
- the oftener even a less important category is planted, the less diversity is realised - negative
- green manure crops help to improve the soil - positive
- a crop disease may remain in the soil until the same crop is planted again, but the longer the farmer waits to plant the same crop again the greater the chance that the disease dies off - positive

- the more a category is repeated for years in a row, the greater the chances diseases get - negative
- Potato crops are particularly sensitive to diseases; planting more often than once in 4 years is considered negative
- Root crops are usually harvested with rather heavy machines which compact the soil – negative
- After some years of cropping, grass is often grown. Planting grass every few years or so is considered as having a positive impact.

Algorithm

We decided that we would determine these characteristics every time for a window of 6 years. So, in order to determine the crop rotation index for year Y, we consider the crops planted in year Y as well as the crops planted in the years Y-5, Y-4, Y-3, Y-2, Y-1 and the year Y itself. The chosen window size could be reconsidered.

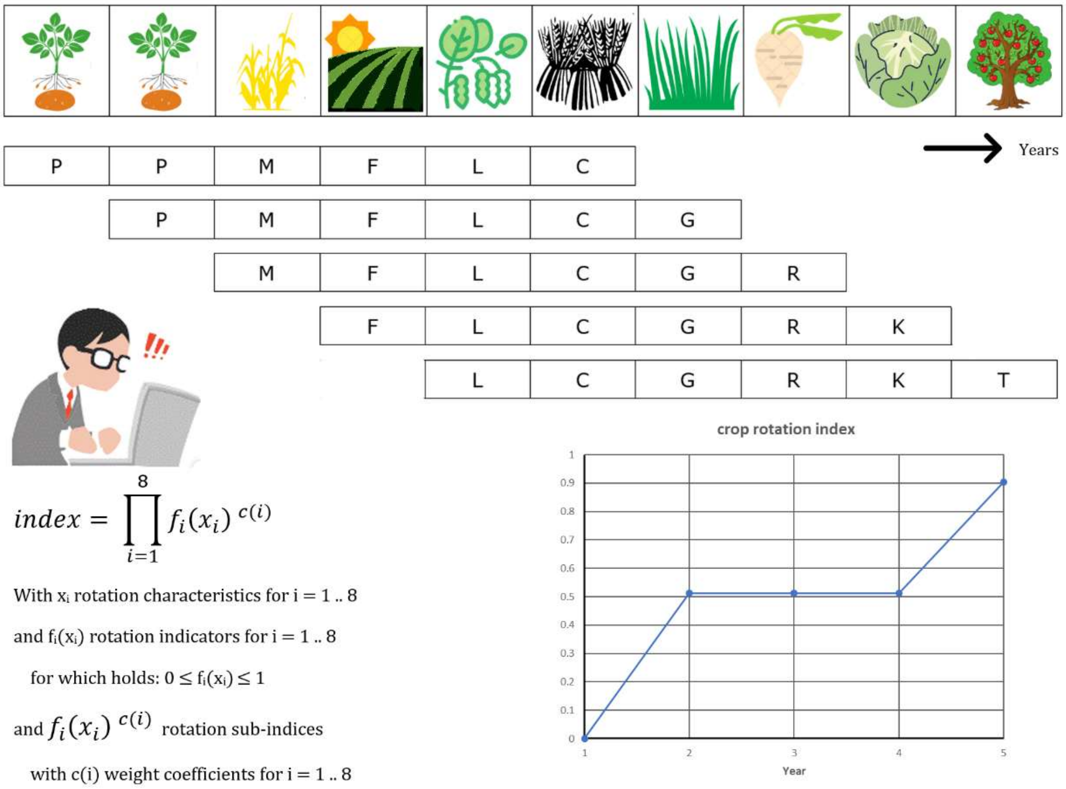
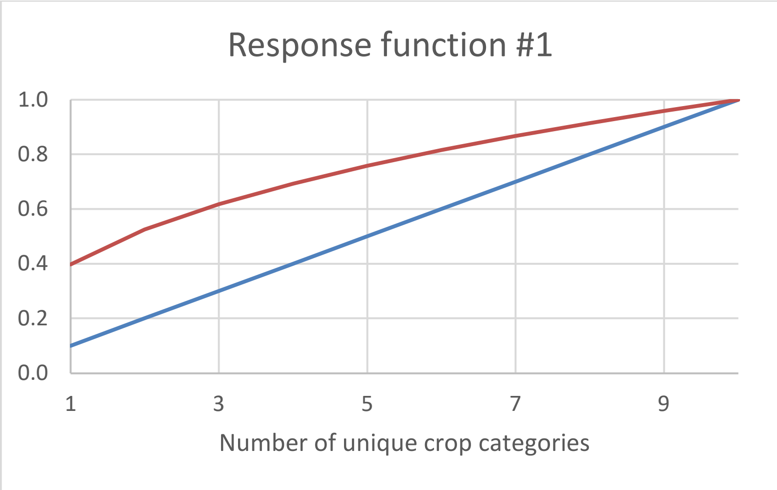


Figure 1: determination of the crop rotation index

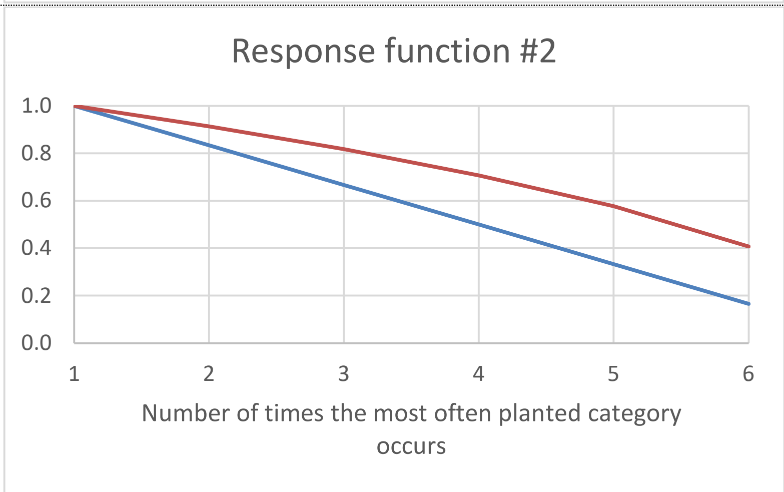
The consequence of choosing a window size of 6 is as follows: when we know which main crops were planted in the past 10 years, we can determine 5 crop rotation indices, as is shown in figure 1.

In order to combine the above-mentioned characteristics or scores into one index, it was decided to introduce response functions. Note that all scores are integers. The response functions have to convert the 8 scores into 8 figures in the range between 0.0 and 1.0 which eventually have to be combined into 1 figure. In the following figures, the response functions are shown in blue.

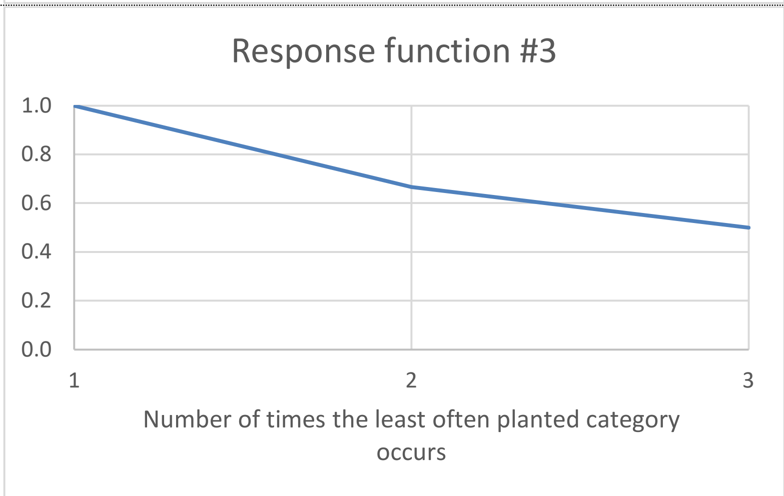
```
With:
x = score
L = window size
N = number of crop categories

def f1(x):
    return x / N
```



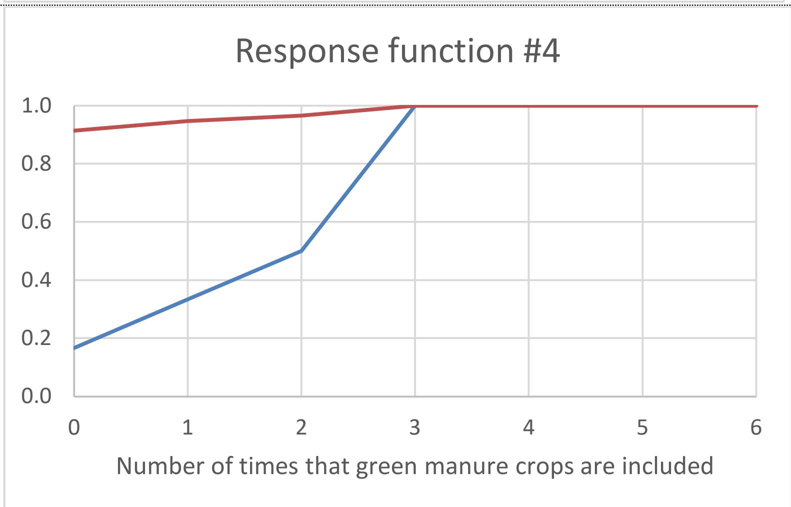

```
def f2(x):
    return (1 + L - x) / L
```



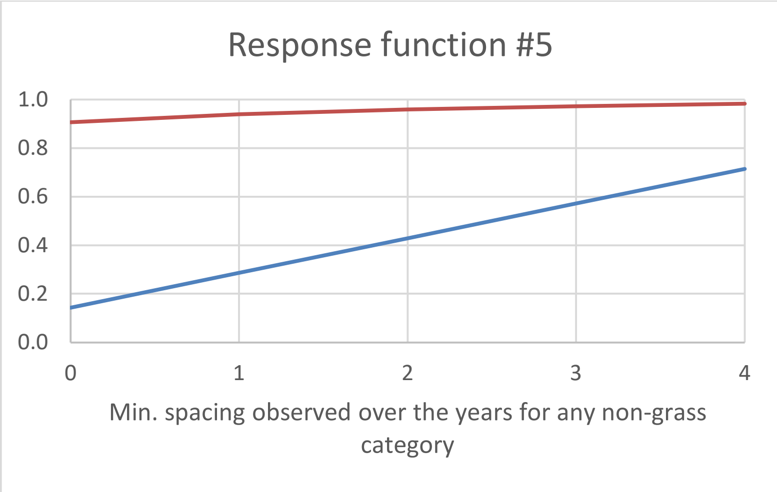

```
def f3(x):
    return 2 / (1 + x)
```



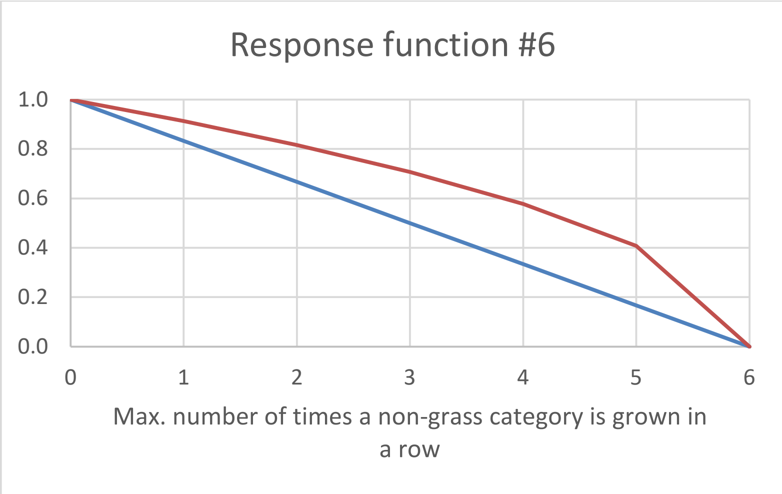

```
def f4(x):
    if x >= (L / 2):
        return 1.0
    else:
        return (x + 1) / L
```



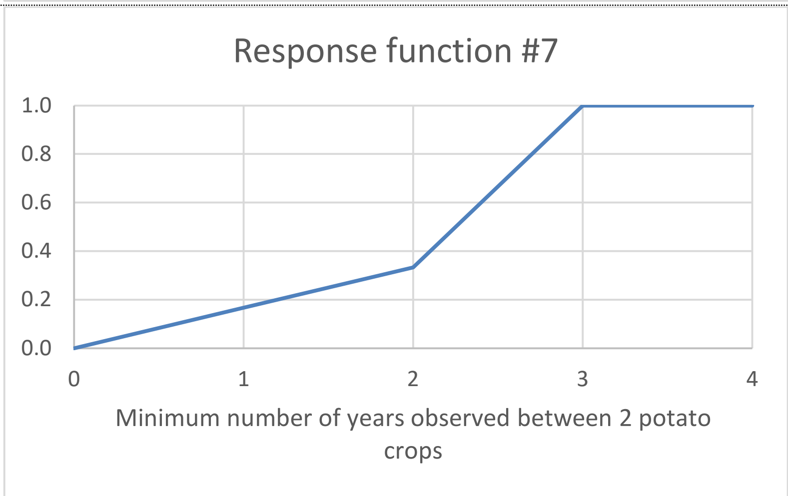
```
def f5(x):
    return (1 + x) / (L + 1)
```



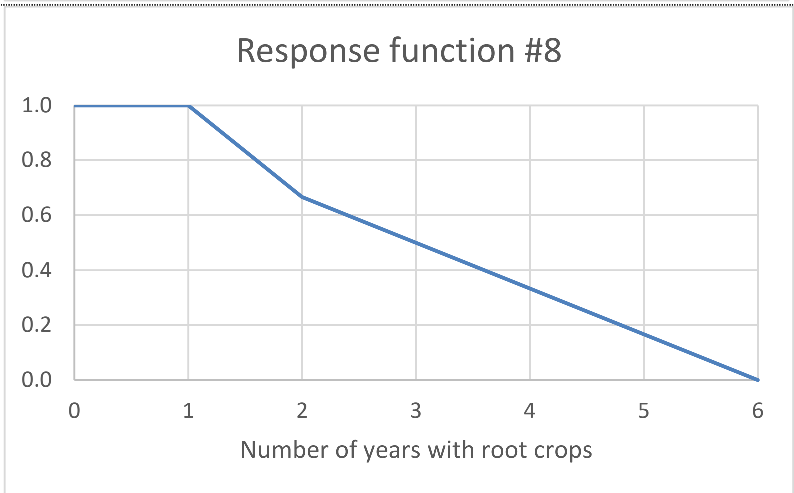

```
def f6(x):
    return 1 - (x / L)
```




```
def f7(x):
    if x < 3:
        return x / L
    else:
        return 1.0
```




```
def f8(x):
    if (x / L) > 0.3:
        return (L -x) / L
    else:
        return 1.0
```



In order to weigh the effect of these response functions, coefficients were introduced. Preliminary values were fixed for these coefficients. The effect of these coefficients can be seen from the red lines. If a response function is shown without red line, then it means that the coefficient was given the value 1 - meaning that the effect is equated to the response itself. Eventually, the weighed results of all the response functions are combined by means of multiplication into one product, the crop rotation index:

$$\text{index} = \prod_{i=1}^{8} f_i(x_i)^{c(i)}$$

with i being the index for the rotation characteristics x_i, with values from 1 thru 8.

The crop rotation index is still under development. E.g. more appropriate values for the coefficients will be determined in the future.

Application

The crop rotation index is therefore an indicator for crop rotation applicable to separate agricultural parcels. Its value may range from 0.0 to 1.0 with the former being the most unfavourable value and the latter being the most favourable one.

For a farm with several fields, values for the crop rotation index can of course be calculated for all fields, provided the main crops are known for the past 6 years. From those values sometimes a weighted average is calculated, taking into account the size of the respective fields. In doing so, higher and lower values are often averaged out. Farmers tend to use a field more intensively when it's located closer to their farm house than fields located further away.

If it is ever considered to use the crop rotation index for determining how farmers should be rewarded for the ecosystem services they provide, the best way would be to do so on a parcel by parcel basis. Over a period of several years, it often happens that a parcel is used by different farmers as a result of sale or lease. It may seem strange to reward a farmer for care which he did not apply to the parcel himself. However, it will become less strange if the special care given to a parcel would be translated into a higher price. In other words: it would be good if the prices of parcels which were given special care would indeed start to reflect such care. Then the prospect of a higher reward will encourage farmers to accept higher prices for well-managed parcels. And the farmers who will buy / lease cheaper parcels will know that the savings they achieve are only temporary. Eventually, the farmers will have to invest into those parcels anyway.