7 A practical case of MCR in the Southwest of the Netherlands

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7.1 Design of the MCR

7.1.1 Preconditions in setting up the rotations

Regional aspects
The main development in vegetable farming in the Southwest of the Netherlands, as described in Chapter 3, is the combination of arable and vegetable crops. Arable farmers include vegetable crops in their rotation while specialised vegetable farmers intensify their cropping plan by including arable crops. Therefore, the aim is to grow fresh market vegetable crops that highly profitable combined with the usual arable crops. The most important vegetable crops in the region were included in Table 3.2. The most important arable crops are potato, sugar beet and cereals.

The experimental farm
The PPO's experimental farming systems are located in Westmaas in the Southwest of the Netherlands (51°47' N.L, 4°30' O.L.) at two meters below sea level. The farm is on marine clay soil with a clay percentage of 32%, organic matter content of 2.3% and a pH (KCl) of 7.3. The groundwater table is at a depth of one meter. The maritime climate has a long-term mean temperature of 9.7°. The mean daily maximum temperature is 13.7° and daily minimum mean temperature is 5.9°. Average rainfall is 790 mm. In Table 7.1, an overview is given of the system's characteristics including the size and layout of the system.

7.1.2 Choice of crops

Fresh market vegetables are the main crops in the rotations. Two model crops are chosen which are representative for most vegetables: iceberg lettuce as labour intensive and Brussels sprouts as labour extensive cabbage crop. Iceberg lettuce is the model for the leafy vegetables group (endive, head lettuce, spinach and other lettuce types). These crops are combined with other vegetable crops, one arable cash crop and the rest crops in the organic as in the integrated system. In this way, the integrated and organic systems are somewhat comparable. The different economic and agronomic characteristics of the chosen potential crops are summarised in Table 7.2. The numbers in the table indicate the relative position; the numbers are explained under the table. Next, the crops are described, but only crops included in the rotation are described.

Brussels sprouts
Brussels sprouts are a very competitive crop that can easily suppress volunteer plants of potato. Mechanical harvest during late cropping activities can have a negative influence on soil structure. Brussels sprouts leave very little mineral nitrogen behind in the soil because they are deep rooting. Depending on the cropping activity, loss of nitrogen from crop residues can occur. It is not advisable to grow the crop in a short rotation together with sugar beets because of infestation by beet cyst nematodes. Pesticide use is high because the growing period is very long and various pests and diseases can threaten product quality. There has to be a continuous nitrogen supply for the crop. Irregular growth has a great influence on quantity and quality of the produce. In conclusion, the crop is hard to grow under purely organic circumstances because of its vulnerability to pests and diseases, and irregular nitrogen supply.

Cauliflower
Cauliflower is placed in the same sequence in the rotation of the integrated system as Brussels sprouts. In the Southwest, the crop is grown more and more on a large scale as winter crop. Harvest is mainly done by manual labour. Pesticide use is quite low because the pests and diseases do not threaten the quality or quantity. The crop is competitive against weeds and volunteer plants.

Iceberg lettuce
Specialised farmers grow the crop on a large scale mostly in rotation with arable crops. The crop is susceptibility to poor soil structure. An early harvest leaves a lot of mineral nitrogen reserves behind which the second crop can use. If iceberg lettuce is grown as a second late crop, the mineral nitrogen reserves can risk leaching after harvesting. Highly mechanised harvest in autumn can have negative effects on soil structure. Iceberg lettuce is very susceptible to aphids, which calls for high pesticide input. Even with this high input, it is not always possible to grow an aphid free crop. In addition, iceberg lettuce has a high risk of failures due to bad weather conditions.

Table 7.1 Overview of the system's layout characteristics of the prototypes in the Netherlands

	Integrated	Organic
System area (ha)	2.8	1
Rotation length (years)	4	6
Number of fields	32	12
Number of rotation blocks	8	2
Mean field size (ha)	0.08	0.075
Mean field length/width ratio	5.6	3.3
Field adjacency[1]	1	1
Adjacency subsequent blocks*	0.25	0.73

* means all fields are adjacent, if subsequent rotation blocks are fully not adjacent, then the rotation in space is optimal and the index is 1

Table 7.2 Potential crops and characterisation

Crop[1]		Iceberg lettuce	Cauliflower	Fennel	Brussels sprouts	Potatoes	Celeriac	Barley
Family/group[2]		1	2	3	2	3	4	5
Economic	Gross margin (k€)	8-10	6-8	6-8	4-6	2-4	2-4	0-2
	Input costs (k€)	6-7	4-5	5-6	3-4 1-2	1-2	0-1	
	Input labour (100 hours)	5-6	3-4	3-5	2-4	0-1	0-1	0-1
Agronomic	Length of growing period (days)	0-60	60-120	60-120	180-240	180-240	120-180	120-180
	Number of crops/year	2-3	2	2	1	1	1	1
	Cover in autumn/winter[3]	2	2	2	2	2	4	4
Soil structure	Rooting[4]	1	3	2	4	2	1	4
	Compaction[5]	0	0	0	3	3	2	1
Crop protection	Input pesticide (kg ha^{-1})	6-8	6-8	0-2	4-6	6-8	10-12	2-4
Weed control	Competitiveness[6]	3	3	2	3	1	4	3
	Mechanical control[7]	1	0	1	0	1	0	0
Fertilisation (N)	Average N- fertilisation (kg ha^{-1})	50-150	250-300	50-150	200-250	200-250	200-250	100-150
	N-off take (kg ha^{-1})	0-50	50-100	0-50	100-150	50-100	100-200	50-150
	Residual-N (kg ha^{-1})	50-100	100-150	50-100	100-150	100-150	100-150	50-100
	Transfer-N (kg ha^{-1})	50-100	50-100	50-100	-	-	-	-
	Transfer-N (kg ha^{-1})	0-50	0-50	0-50	0-50	0-50	0-50	0-50

1. Crops in order of profitability
2. Genetically and phyto-pathologically related groups: 1 = Compositeae, 2 = Cruciferae, 3 = Umbrellifereae, 4 = Solanaceae, 5 = Gramineae
3. 4 = no cover in autumn and winter, 2 = no cover in autumn or winter, 0 =all others; (green manure crops included)
4. 0 = poor superficial rooting, 4 = deep intensive rooting
5. Crop, cropping practices, soil, harvest time and harvest technique determine the intensity of compaction: 0 = very light compaction, 4 = intensive and serious compaction
6. 0 = very poor weed suppression, 4 = strong weed suppression
7. 0 = weed control completely mechanical, 4 = no mechanical weed control possible

Fennel
In the Southwest region, fennel is increasingly grown on a large-scale. Pesticide use in fennel can be quite low. Apart from an occasional aphid attack, there are no pests or diseases that seriously threaten the crop. The crop is not very competitive against weeds. Input of herbicides in combination with mechanical control is necessary to limit too much manual labour. After late harvests, mineral nitrogen reserves left behind combined with nitrogen from crop residues means a risk of nitrogen leaching.

Celeriac
The Southwest is a main production area for celeriac. In its early stage, the crop is not very competitive with weeds. However, weed control can be carried out completely mechanically. Fungal diseases can cause a need for high fungicide use.

Potato
Potato is the most profitable arable crop. This crop has the risk of leaving volunteer plants in the next crop. Therefore, preferably a highly competitive crop has to follow potato in the rotation. Late blight in potato calls for high fungicide input. In the organic system, this means that the crop has to be harvested early.

Barley and winter wheat
Cereals are not attractive as cash crop, but have a positive effect on soil structure because of their deep intensive rooting. The choice of a summer or winter cereal is dependent on the harvest time of the previous crop. Spring cereals allow the possibility of using a catch crop in autumn. In addition, under sowing of white clover is more successful in spring cereals (organic system). Winter cereals provide the advantage of soil cover in the winter.

Other crops are not feasible in the rotation. Carrots, although having a large acreage in the region, are not grown because the soil at the experimental location is too heavy. Papilionaceous crops (beans) are not chosen because the aim is for highly profitable fresh market crops. Potato is chosen as arable crop because of its

Table 7.3 Chosen variants for the integrated crop rotation, variant 1 and 2 differ in vegetable cropping activities, variant 8 is not irrigated

	Crop rotation variant						
year	1	2	3	4	5	6	7
1	potato	potato	potato	potato	potato	potato	potato
2	Brussels sprouts	Brussels sprouts	Brussels sprouts	Brussels sprouts	fennel	celeriac	cauliflower
3	spring barley	spring barley	spring barley	spring barley	winter wheat	winter wheat	winter wheat
4	fennel	fennel	celeriac	iceberg lettuce	iceberg lettuce	iceberg lettuce	iceberg lettuce

profitability and large acreage. Therefore, other arable crops (as sugar beet and onion) are not taken into account.

7.1.3 Planning the MCR

Cultivation intensity and choice of crop types
A four-year rotation is standard for conventional arable farms. The standard arable rotation is potato, sugar beet, cereal, and a fourth (mow) crop. When including vegetable crops in arable rotations, a four-year rotation is used as well. The usual combination of crops is 50% fresh market vegetables, 25% arable cash crops (potato or sugar beets) and 25% cereals. The rotations in the integrated system will be planted for four years with the above-mentioned set-up.

In organic farming, a six-year rotation is considered as optimal agronomically. This length of time is necessary for successful prevention of pests and diseases. Also, the possibilities for nitrogen input are limited. An optimal combination of highly demanding (mostly vegetables) and undemanding crops (cereals) has to be found. When the rotation is longer, this is more possible. Therefore, a six-year rotation has been chosen in the organic system. In this rotation, the aim is to include 50% of fresh market vegetables, 33% with tertiary crops (cereals) and 17% with arable cash crops.

To cover the most possible cropping activities and the most important crops, it is necessary to plan different variations. Seven variants in the integrated system and two variants in the organic system were set up. The following section explains how the rotations were set up.

Integrated systems
Brussels sprouts and iceberg lettuce were chosen as main crops in the integrated systems. Each variant contained one of these crops in combination with one other labour intensive or extensive vegetable crop. Fennel was chosen as intensive crop and celeriac as extensive crop. Both of these are umbellifereaous crops, which makes them representatives of a different plant family as the chosen main crops. There were two variants with Brussels sprouts and fennel in order to test different cropping activities. One variant consisted of iceberg lettuce and cauliflower. Each variant contained potato as arable cash crop and barley or winter wheat as cereal crop.

The most structure sensitive and most profitable crops such as iceberg lettuce and fennel are grown after cereals. When both crops are in the same rotation, iceberg lettuce is grown after the cereal. The Brassica crops are grown after potatoes because of the good possibility to control volunteer potato plants. Whenever possible, catch crops are grown. This is only possible when the field is clear before mid-August. Non-leguminous crops are chosen to lower the mineral nitrogen content of the soil in autumn.

After all factors were considered for the cropping plan and rotation, the rotation variations given in Table 7.3 were chosen. When discussing the results variant one to four are discussed together in system NL INT1 and variant five to seven are discussed together in system NL INT2. In Figure 7.1, the crop rotations over time for the integrated rotation variants are shown. In winter period, there is no soil cover. Other than winter wheat, there are no winter crops. Ploughing has to be done before winter because the soil is too wet in spring. Planting normally starts in the second half of March. Between two crops in the same year, there is a short fallow period of 2-4 weeks.

Organic system
The motivation for the choice of the crops in the organic system (NL ORG) is the same as for the integrated systems: iceberg lettuce is chosen as representative for the leafy vegetables and Brussels sprouts as a representative for the Brassica crops. The third vegetable crop is fennel as representative of a labour intensive crop from a different plant family. The rotation is completed with potato as arable cash crop and with two cereal crops to improve soil structure and to lower nitrogen demand. The two variants of the organic system only differ in the chosen cropping activities of the vegetable crops.

Minimising nutrient losses and optimising nutrient availability were leading factors in planning the rotation (see 7.2 and Integrated and Ecological Nutrient Management manual, VEGINECO project report no. 3). Therefore, nitro-

Table 7.4 Rotation and fertilisation of the organic system

Year	Crop	organic fertilisation	remarks
1	iceberg lettuce	before crop, liquid cow manure	two plantings
2	winter wheat or barley	solid cow manure after cereal	under sowing of clover in cereal
	white clover		
3	Brussels sprouts	before crop, liquid cow manure	
4	fennel		one or two plantings
5	winter wheat or barley	solid cow manure after cereal	under sowing of clover in cereal
	white clover		
6	potato		
	vetch/grass		catch crop

gen-demanding crops are altered with undemanding crops. In addition, effective weed control and prevention of negative affects on soil structure were important aims in setting up the rotation. Whenever possible, catch crops were grown. This was only possible when the field was cleared before mid-August. Leguminous crops were chosen as green manures to bring extra nitrogen into the system. White clover was grown in combination with the cereal crop (under sowing) to add nitrogen to the system through nitrogen fixation. Vetch with grass was grown after potato.

The two cereal crops had to be divided equally over the rotation. The crops with potentially the most negative effects on soil structure were potato and Brussels sprouts. Therefore, these crops were equally divided over the rotation as well. Both iceberg lettuce and fennel probably leave some remaining weeds behind. Therefore, a cereal crop after these crops helps to control these weeds. Additionally iceberg lettuce and fennel leave a lot of mineral nitrogen and nitrogen in crop residues behind. This calls for a follow up of crops such as cereals with a deep and intensive rooting in order to use a part of this

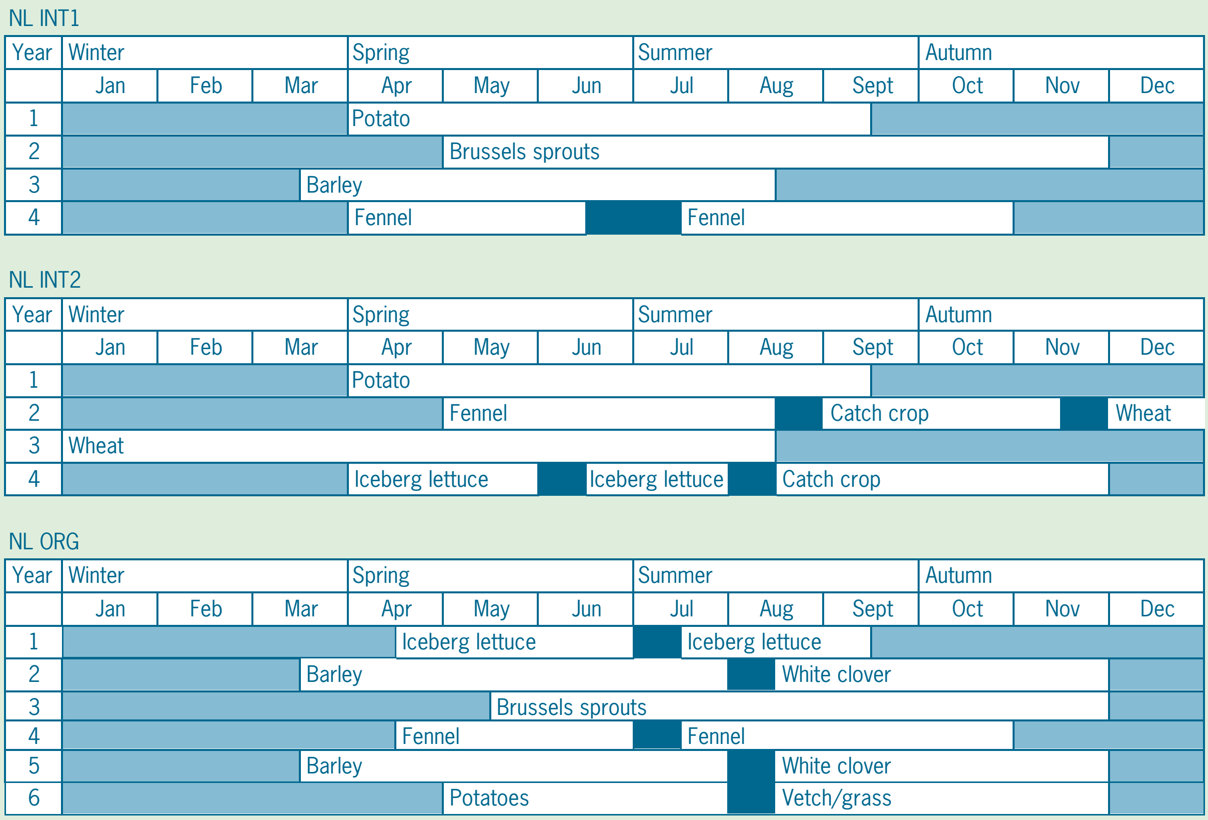

Figure 7.1 Examples of Multifunctional Crop Rotation represented over time of cropping variant 2 of NL INT1, cropping variant 5 of NL INT2, and cropping variant 1 of NL ORG

nitrogen in the next season. Fennel is not very competitive against weeds so this crop needs very clean conditions, which is possible after Brussels sprouts. Potatoes leave a lot of mineral nitrogen reserves and nitrogen in crop residues behind. Because the crop is harvested early, the cultivation of a catch crop was possible. The catch crop can also improve the soil structure after potato. The organic crop rotation is given in Table 7.4. The division of the crops over time is given in Figure 7.1.

7.1.4 Agro-ecological layout

Figure 7.1 shows the layout of the systems over time, Figure 7.2 shows the layout of the systems in space. As indicated in Table 7.1, all fields are adjacent. The different variations were mixed to make cultivation of the crops easier. As much as possible, fields with the same crops were put together. It was not possible to avoid placing subsequent blocks next to each other in both systems.

7.2 Testing and improving

7.2.1 Results per parameter

Almost all parameters have some relationship with MCR. In this paragraph, the parameters with close relationships to the MCR method are examined. In Tables 7.5 and 7.6, an overview of the parameter values is given for the NL INT1 and NL ORG.

Quality and quantity of production (QLP/QNP)

In the integrated systems, the actual levels for quantity and quality almost reached the desired levels. It is assumed that nutrient availability is sufficient to reach yield quantity and quality targets. Yield quantity and quality is most influenced by external factors (weather), diseases and plagues.

For organic farming, there is hardly any data available

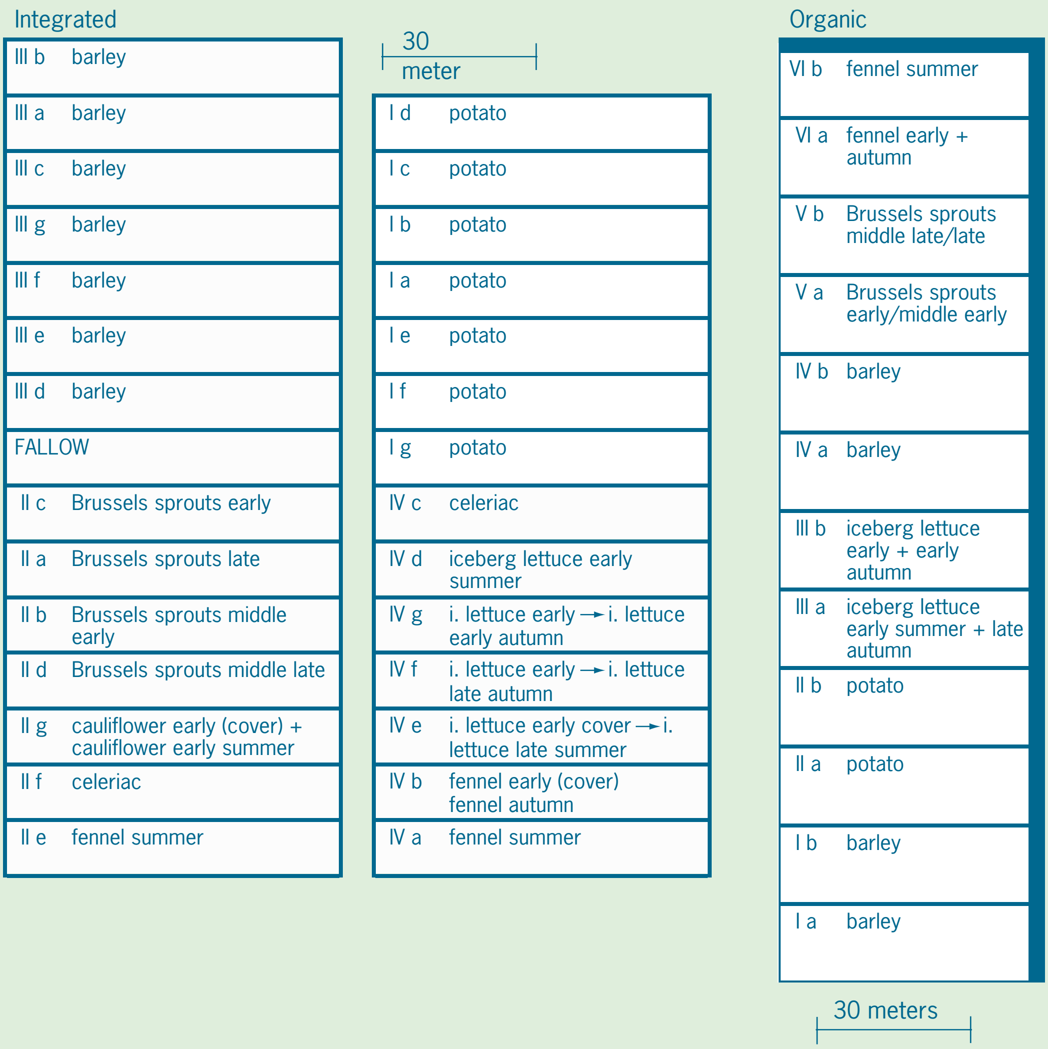

Figure 7.2 Map of the integrated and organic system Westmaas, I-VI = crop rotation block 1997, a - h = cropping variant, ▬ = part of ecological infrastructure

Table 7.5 Desired and achieved results for parameters in NL INT1 with close relationships to MCR

Theme	Parameter	Desired results	Actual results 1997	1998	1999	2000
Quality Production	QNP	1.0 (GAP)	0.95	0.71	0.90	0.96
	QLP	1.0 (GAP)	0.99	0.92	0.80	0.88
Farm Continuity	NS	>€ 0 ha^{-1}	-1 356	399	-2 040	-2 698
	HHW	<15 hours ha^{-1}	-	19	12	10
Sustainable use of Resources	PAR	20<Pw-count<30	30	28	29	24
	KAR	20<K-count<29	26	24	23	23
	OMAB	>1.0	1.5	1.7	1.5	1.4
Clean Environment Nutrients	PAB	1.0	1.15	0.91	0.81	1.06
	KAB	1.0	0.84	1.25	1.04	1.03
	NAR	<70 kg ha^{-1} (0-100 cm)	58	25	33	32
Clean Environment Pesticides	PESTAS	<5.9 kg ha^{-1}	3.3	1.9	1.5	2.5
	EEP-soil	<240 kg days ha^{-1}	250	226	155	167
	EEP-air	<0.45 kg ha^{-1}	0.64	0.57	0.51	0.66
	EEP-groundwater	<0.5 ppb	5.98	4.83	4.77	0.01

to support the quantification of the Good Agricultural Practices in terms of yield and quality. The calculated QNP and QLP are averaged over all the crops in one system. QNP varied from 66 to 89% of the target values and QLP improved over the years by 10%. In addition, problems in crop protection and nitrogen supply needs to be improved for all crops to reach target values.

In the integrated systems, quantity of production did not reach targets for iceberg lettuce and cauliflower. Quality of production is too low for almost all crops except celeriac and the cereals. In the organic system, the most problematic crops were Brussels sprouts and iceberg lettuce. Except for Brussels sprouts, quality in the organic system reached target values. Quality of Brussels sprouts is very low because of slugs and insufficient nitrogen availability. These causes have no direct relationship with MCR.

Differences between integrated and organic systems were small for most crops. Only for Brussels sprouts (quality and quantity), potato (quality) and cereal (quantity) are the differences large. Variation between years is, however, large.

Net surplus (NS)

The calculations of net surplus are based on a farm size of 47 hectare for NL INT1 and 28 hectare for NL INT2 and NL ORG. The gross revenues are yield times actual price. Fluctuating product prices mainly influenced the fluctuation in the gross revenues. Unfortunately, the average price level in the testing period was very low which negatively influenced the economic performance. The organic farm has higher costs per hectare, but still had positive net revenues mainly because of the higher prices for organic produce.

Hours hand weeding (HHW)

In the integrated systems, hours of hand weeding almost

Table 7.6 Desired and achieved results for parameters in NL ORG with close relationships to MCR

Theme	Parameter	Desired results	Actual results 1997	1998	1999	2000
Quality Production	QNP	1.0 (GAP)	0.72	0.73	0.85	0.61
	QLP	1.0 (GAP)	0.49	0.64	0.65	0.71
Farm Continuity	NS	>€ 0 ha^{-1}	2 439	2 837	1 167	-2 135
	HHW	<15 hours ha^{-1}	-	26	34	62
Sustainable use of Resources	PAR	20<Pw-count<30	29	29	29	23
	KAR	20<K-count<29	25	24	25	25
	OMAB	>1.0	1.4	1.3	1.4	1.4
Clean Environment Nutrients	PAB	1.0	0.70	0.93	1.19	1.42
	KAB	1.0	2.62	0.93	1.77	1.85
	NAR	<70 kg ha^{-1} (0-100 cm)	80	14	52	41

reached target values. However, in the organic system, there is still too much manual labour. Mechanical weed control needs to be further improved. In addition, a thistle and cale infection from previous cultivations at the start of the system made extra manual weeding hours necessary.

Sustainable use of resource parameters (OMAB)
Some crops contribute much more to the effective organic matter input because of a large amount of crop residues (Brussels sprouts, cereals) or because of the input of paper pots in which they are planted (iceberg lettuce, fennel). In addition, green manure crops bring effective organic matter in the system. The input of effective organic matter with crop residues, paper pots and green manures is more than sufficient to compensate for decomposition of a soil's organic matter in both types of systems. MCR has great influence on the input of effective organic matter in these systems.

Nutrient parameters (NAR)
In most years, the NAR was lower than the target level of 70 kg ha-1 in NL ORG as well as in NL INT1. The NAR on farm level is very dependent of the type of crops in the rotation. In the integrated system (Brussels sprouts), no crop had a high NAR, thus the farm level is relative low. In NL INT2, the actual level is close to the desired level (69 kg ha-1) because of the high NAR after the cultivation of iceberg lettuce. This indicates that MCR can have a great influence on the NAR of the system. In the organic system, iceberg lettuce and potato caused a high NAR. Iceberg lettuce had a high NAR because of low efficiency and large amounts of crop residues. Potato in the organic system had a high NAR because it was harvested too early due to late blight.

7.2.2 Optimisation of the MCR

This section describes the improvements made to the MCR while testing to make the system perform better and reducing the parameters' shortfall.

NL INT1
Over the four years of testing and improving, the Multifunctional Crop Rotation for the integrated systems were only slightly altered. Extra catch crops, whenever possible, were placed in the rotation although possibilities were limited because of weather conditions and harvest times. By growing these catch crops, the amount of mineral nitrogen in autumn could be lowered. After iceberg lettuce, cauliflower and fennel, phacelia, white mustard, Italian ryegrass or fodder radish was grown. Between two cultivations in one year of iceberg lettuce, a little more time was taken in order to increase the supply of nitrogen from crop residues from the first crop. The reason for this measure was the amount of mineral nitrogen in autumn was lowered as well. Finally, varieties were changed in order to have crops that have a better yield (quantity and quality) or that are more resistant against pests and diseases. Other varieties were chosen in fennel to reduce the cracking of bulbs, and in Brussels sprouts for a better resistance to aphids, Albugo candida and mildew.

NL ORG
More changes were made in the MCR of the organic system. The most important change was the replacement of one cereal crop with white clover under sowing by grass clover. This was done because the amount of nitrogen brought into the system by the clover was limited because the under sowing was not working very well. The grass clover mixture reduced the risk of failure due to nitrogen fixation. In addition, in the grass clover there were fewer slugs because it was mowed.

The replacement of the leguminous vetch with a non-leguminous catch crop after potato was the second important change. It appeared that the mineral nitrogen content after harvest of potato was very high. Therefore, it was more important to prevent the mineral nitrogen for leaching than bringing extra nitrogen into the system by fixation. Different kinds of catch crops were tested (white mustard, phacelia and fodder radish.

In the integrated systems, extra catch crops, whenever possible, were placed in the rotation and the time between two cultivations in one year of iceberg lettuce was longer to lower the mineral nitrogen content in autumn.

Brussels sprouts varieties were changed to varieties with better resistance to diseases and lower nitrogen demands. Barley was replaced by spring wheat in some systems to have better results with under sowing of clover. Varieties of grasses, clover and other green manure crops were judged on the attractiveness for slugs. The grass clover mixture was changed to more white clover and other grass varieties were chosen with better resistance to crown rust.
Finally, planting distance of iceberg lettuce was increased to get better product quality, better nitrogen availability and fewer problems with downy mildew.