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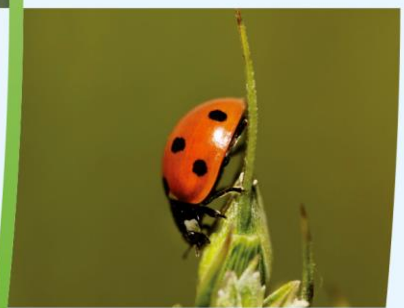
Report 1740.N.18

Input values for the organic matter balance: catch crops and crop residues



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Input values for the organic matter balance: catch crops and crop residues

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Ministerie van Landbouw, Natuur en Voedselkwaliteit

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Summary and conclusions

Organic matter and carbon in the soil is of importance for agricultural purposes because of its' huge impact on soil quality, but it is also of relevance for mitigation of and adaptation to climate change. The organic matter balance is available for farmers in the Netherlands to evaluate whether their organic matter management is sustaining soil organic matter contents. It is expected that the basic estimation values for organic matter input by crop residues and green manure/ catch crops need to be updated since they have mainly been published in 1989. Since then, crop breeding efforts have succeeded to improve crop varieties to higher crop and/ or biomass yields going along with changes in harvest index (ratio between harvested product and crop residues) and/or above:belowground biomass ratios. The objective of this study is to explore whether the values of effective organic matter for residues of arable and vegetable crops and catch crops are still valid or whether they should be updated.

Therefore, data about the biomass of residues of most common arable crops in the Netherlands (potato, sugar beet, spring barley, winter wheat), some vegetable crops (grain maize, leek and pea) and silage maize, as well as for green manure and catch crops (fodder radish, yellow mustard, winter rye, oats, Italian ryegrass, English ryegrass, common vetch and tagetes) were collected from scientific and grey literature. In total, data of 11 publications (4 for arable, 8 for catch crops and green manures) were integrated to create the database analysed further in this report. Most of the collected data were expressed in dry biomass, which was transferred to organic matter assuming 90% of organic matter in the dry matter. Organic matter was transferred to Effective Organic Matter (EOM) by multiplying with humification coefficients (in general 0,2-0,3 for above-ground biomass and 0,35 for belowground biomass). In some studies, data about belowground biomass were not available. In those cases, crop specific assumptions of belowground biomass were made.

The differences between the current average values of effective organic matter (EOM) input with catch crops and green manure crops and the EOM as calculated from literature data is small. Besides for Italian ryegrass grown in stubble the difference is smaller than 20%. For Italian ryegrass grown in stubble the current value is about 30% lower than the literature average. However, the variation around the averages was large, and it seems to be worthwhile to take into account these variations in the organic matter balance.

If we consider the contribution of crop residues of arable crops to the organic matter balance, the EOM input by crop residues of potato appears to be smaller than the current values, according to literature. For leek the current data are in a similar range than the literature averages. The average EOM input by crop residues of sugar beet appears to be slightly lower than the current value of 1275 kg EOM per ha, which can be explained by the lower amount of biomass in the leaves of the newer varieties and differences in the harvesting method. For pea and spring barley the average based on literature data and the current value are similar. The data for winter wheat show similar values as today's values for belowground but not for aboveground biomass. Independently of whether straw is harvested or left as residues, literature data indicate much smaller EOM input of aboveground residues than the current values for winter wheat.

Conclusions

- Currently used values for the EOM supply by catch crops are in line with values from literature, but represent well established catch crops only. However, our data suggest that in practice large variations around average values of catch crop biomass occur in dependence of sowing date, etc. That should be taken into account in an improved version of the organic matter balance.
- For arable crops, the collected data on biomass production and associated amounts of (effective) organic matter are quite different from the current values, but not enough data are available for a change.
- Based on several review articles, it is difficult to make an accurate estimation of the biomass (and effective organic matter supply) of crop residues of arable crops at the basis of crop yield. Other management factors,

like the fertilisation level, may have a large effect on amount of crop residues, in particular the above:belowground biomass ratio.

- At the basis of a quick scan of humification coefficients, it can be concluded that reported humification coefficients for belowground biomass vary and for aboveground residues and catch crops all go back to the same source.

Recommendations

- It is recommended to replace current values of effective organic matter supply by catch crops on the organic matter balance by values which depend on the (foreseen) development of the catch crop (bad, good or very good). That should be taken into account in an improved version of the organic matter balance:
    - If the organic matter balance is used as a planning instrument, an estimation of the foreseen development of catch crops (bad, good or very good) can be made at the basis of the planned sowing dates.
    - If the organic matter balance is used as a monitoring tool, the actual biomass production of catch crops could be taken into account. Pictures maybe helpful to be able to distinguish between poorly, normally or well developed catch crops. A similar method is in use in France. More advanced methods to estimate the biomass production, could be based on sensing technologies.
- Because a limited amount of data about biomass of and organic matter supply by crop residues was found within the scope of this study, it is not recommended to change the current values. A more extensive evaluation is recommended.
- Based on the review of humification coefficients, it can be concluded that not enough experimental data on this topic is available. This appears to be a good reason to carry out additional work on this topic.

Samenvatting en conclusies

Organische stof (OS) is van belang voor de landbouwkundige productie vanwege het grote effect op bodemkwaliteit, maar organische (kool)stof is ook van belang voor klimaatadaptatie en -mitigatie. De OS-balans is een tool die beschikbaar is voor boeren en adviseurs om na te gaan of een bepaald OS-beheer leidt tot handhaving van OS-gehalten in de bodem. Een update van kengetallen voor de OS-aanvoer met gewasresten en/of groenbemesters of vanggewassen is gewenst, aangezien de huidige kengetallen dateren van 1989 of daarvoor. Sindsdien heeft veredeling geleid to nieuwe rassen met hogere opbrengsten en mogelijke veranderingen in de harvest index (verhouding tussen oogstproduct en gewasrest) en/of de verhouding tussen boven- en ondergrondse biomassa. Het doel van deze studie is om na te gaan of de hoeveelheid effectieve organische stof (EOS; de hoeveelheid OS die resteert na 1 jaar) van gewasresten van akkerbouw- en groentegewassen en groenbemesters, die worden gebruikt in de OS-balans, nog geldig zijn of aangepast moeten worden.

Daarom zijn literatuurgegevens verzameld van de hoeveelheid gewasresten van enkele grote akkerbouwgewassen (aardappelen, suikerbieten, zomergerst en wintertarwe), enkele groentegewassen (prei, korrelmaïs en erwt), snijmaïs en groenbemesters of vanggewassen (bladrammenas, gele mosterd, rogge, Japanse haver, Italiaans raaigras, Engels raaigras, voederwikke en tagetes). In totaal zijn data verzameld uit 11 publicaties (4 voor akkerbouwgewassen en 8 voor groenbemesters of vanggewassen), die zijn gebruikt voor het opgebouwde databestand. De meeste van de verzamelde gegevens waren uitgedrukt in drogestof, dat is omgerekend naar organische stof door uit te gaan van een OS-gehalte in de drogestof van 90%. Organische stof is omgerekend naar EOS op basis van humificatiecoëfficiënten van 0,2-0,3 voor bovengrondse biomassa en 0,35 voor ondergrondse biomassa. In studies waarin geen gegevens van ondergrondse biomassa beschikbaar waren zijn daarvoor aannames gedaan.

De verschillen tussen de gemiddelde waarden voor de EOS-aanvoer met groenbemesters die momenteel worden gehanteerd en de EOS die is berekend op basis van literatuurgegevens zijn klein. Met uitzondering van Italiaans raaigras gezaaid in de stoppel, waarbij de huidige waarden ca. 30% lager zijn dan de waarden die zijn berekend op basis van literatuurgegevens, waren de verschillen kleiner dan 20%. De spreiding rond de gemiddelde waarden was echter groot, en het is gewenst daar beter rekening mee te houden.

Op basis van de literatuurgegevens lijkt de EOS-aanvoer met gewasresten van aardappelen lager te zijn dan de waarde die momenteel wordt gehanteerd. Dat geldt ook voor de EOS-aanvoer met gewasresten van suikerbieten, wat kan worden verklaard door nieuwe rassen en gewijzigde oogstmethodes, waarbij een kleiner deel van de oostresten op het land achterblijft. Voor zomergerst, prei en erwt is de EOS-aanvoer op basis van literatuurgegevens vergelijkbaar met de huidige kengetallen. De literatuurgegevens van wintertarwe laten voor de ondergrondse biomassa vergelijkbare waarden zien als de huidige kengetallen, maar dat geldt niet voor de bovengrondse biomassa. Zowel voor de situatie waarbij stro achterblijft als voor de situatie waarbij het wordt afgevoerd, zijn de cijfers op basis van de literatuur lager dan de cijfers die momenteel worden gebruikt in de OS-balans.

Conclusies

- Huidige waarden voor de EOS-aanvoer met groenbemesters komen overeen met literatuurgegevens, maar hebben alleen betrekking op goed ontwikkelde groenbemesters. Uit de literatuurgegevens blijkt dat er in de praktijk een grote spreiding voorkomt in de EOS-aanvoer met groenbemesters, afhankelijk van zaaidatum en omstandigheden tijdens de zaai- en groeiperiode. In een verbeterde versie van de OS-balans moet meer rekening worden gehouden met de spreiding rond de gemiddelde EOS-aanvoer van groenbemesters.
- Bij de akkerbouwgewassen werden er aanzienlijke verschillen vastgesteld tussen de EOS-aanvoer met gewasresten die zijn afgeleid van literatuurgegevens enerzijds en de waarden die momenteel worden

gebruikt voor de OS-balans anderzijds. Er zijn echter niet voldoende literatuurgegevens verzameld om te komen tot een aanpassing van de huidige waarden.
- Op basis van enkele overzichtsartikelen is het moeilijk om te komen tot een nauwkeurige schatting van de hoeveelheid biomassa (en EOS-aanvoer) in gewasresten van akkerbouwgewassen op basis van de opbrengst. Andere factoren, zoals het bemestingsniveau, hebben een groot effect op de hoeveelheid gewasresten en de verhouding tussen onder- en bovengrondse biomassa.
- Op basis van een quick-scan van humificatiecoëfficiënten (hc's), kan worden geconcludeerd dat gerapporteerde hc's van ondergrondse biomassa verschillen en dat ze voor bovengrondse gewasresten en groenbemesters allemaal zijn te herleiden tot dezelfde bron.

Aanbevelingen

- We bevelen aan om de huidige kengetallen voor de EOS-aanvoer met groenbemesters op de OS-balans te vervangen door waarden die afhankelijk zijn van de (voorziene) ontwikkeling van groenbemesters (goed, normaal, slecht). In een verbeterde versie van de OS-balans kan daarmee rekening worden gehouden op de volgende manieren:
    - Als de OS-balans wordt gebruikt voor de planning, kan een inschatting worden gemaakt van de verwachte ontwikkeling van groenbemesters (goed, normaal, slecht) op basis van de verwachte zaaidata.
    - Als de OS-balans wordt gebruikt voor monitoring, kan rekening worden gehouden met de actuele ontwikkeling van groenbemesters. Foto's kunnen worden gebruikt om een globale indicatie van de ontwikkeling van de groenbemester te krijgen. Een vergelijkbare methode wordt in Frankrijk gebruikt om de biomassaproductie van groenbemesters in te schatten. Meer geavanceerde methoden om de biomassaproductie (en daarmee de EOS-aanvoer) te kwantificeren kunnen worden gebaseerd op sensormetingen (b.v. van de bodembedekking).
- Aangezien de hoeveelheid verzamelde gegevens van de biomassa van gewasresten van akkerbouw- en groentegewassen beperkt was, wordt aanbevolen de huidige kengetallen voor de EOS-aanvoer niet aan te passen. Een uitgebreidere verkenning is zinvol.
- Op basis van de verzamelde informatie over humificatie-coëfficiënten, kan worden geconcludeerd dat hiervan onvoldoende onderzoeksgegegevens beschikbaar zijn. Daarom wordt aanbevolen om hiernaar aanvullend onderzoek te doen.

1 Introduction

The organic matter balance is available for farmers in the Netherlands to evaluate whether their organic matter management is sustaining soil organic matter contents. Having a good estimate of the input of organic matter or carbon to the soil is not only important in the agronomic context of soil fertility management. Also, regarding climate change, its' effects on mitigation (carbon storage by increasing soil organic matter contents and/or minimising greenhouse gas emissions) as well as adaptation (improving soil resilience to drought and precipitation peaks) are of relevance and also for that reason it is important to estimate carbon inputs to the soil as accurately as possible. For political reasons, an accurate estimation of the carbon input is particularly relevant when farmers are rewarded or certified for climate friendly farming and carbon storage at the basis of the result of the organic matter balance.
The current balance method is based on the basic principle that the amount of organic matter that should be applied to the soil each year should compensate the amount of soil organic matter that is mineralised in one year. The comparison of organic matter inputs and the loss of soil organic matter by mineralisation is called the organic matter balance. To calculate the input of organic matter to the soil with crop residues, green manures and catch crops as well as animal manures and other organic amendments, basic estimation values of the amount of effective organic matter are published (Handboek Bodem en Bemesting, 2018c). These values are calculated from the biomass and organic matter input and the so called humification coefficients which indicate crop specifically which part of the organic matter is left in the soil after one year (e.g. De Haan, 1977).
The central question within this study is whether the values of effective organic matter for residues of arable and vegetable crops and catch crops are still valid or whether they should be updated. Today's online published values for inputs to the organic matter balance (Handboek Bodem en Bemesting (2018b) and (2018c)) are in most cases the same as those published in 1989 (PAGV, 1989; table 1), at least for the crops we investigated here. An extract of online published current values can be found in Annex 1.

Table 1 Overview of effective organic matter values in above- and belowground plant parts [kg ha^{-1}] of arable crops and catch crops (PAGV, 1989).

Crop category	Crop	aboveground	belowground	total
Arable crops	Potato (ware)	700	175	875
	Leek	na	na	100
	Leek (residues ploughed in)	na	na	450
	Sugar beet (head and leaf included)	1100	175	1275
	Pea	na	na	1000
	Spring barley (incl. straw)	1590	350	1940
	Spring barley (excl. straw)	960	350	1310
	Winter wheat (incl straw)	2070	560	2630
	Winter wheat (excl. straw)	1080	560	1640
	Grain maize	1500	700	2200
	Silage maize	150	525	675
Catch crops	Fodder raddish (seeded after cereals)	na	na	850
	Yellow mustard (seeded after cereals)	na	na	850
	Winter rye	na	na	850
	Italian ryegrass (sown in stubble)	660	420	1080
	English ryegrass (sown under cover crop)	560	595	1155
	Vetch (seeded after cereals)	na	na	645
	Tagetes	na	na	865

It is expected that the basic estimation values for organic matter input by crop residues and green manure/ catch crops need to be updated since they have mainly been published in 1989 (PAGV, 1989). Since then, crop breeding efforts have succeeded to improve crop varieties to higher crop and/ or biomass yields going along with changes in harvest index (ratio between harvested product and crop residues) and/or above:belowground biomass ratios.

Therefore we collected recent data of above- and belowground biomass yields (with a distinction between harvest product and crop residues) from grey and scientific literature about field experiments in the Netherlands as well as in other European countries. Besides biomass, humification coefficients (HC's) are of importance for the values of the amounts of effective organic matter (EOM). Because we did not expect large changes of HC's, we focused on eventual changes in the amounts of biomass inputs by crop residues and catch crops. The values of EOM based on recent data of above- and belowground biomass were compared with the current basic values of EOM published on the website for official farmers' advice in the Netherlands (Handboek Bodem en Bemesting, 2018c).

2 Material and Methods

2.1 Used data sources

Data about above- and belowground biomass of residues of most common arable crops in the Netherlands (potato, sugar beet, spring barley, winter wheat), some vegetable crops (grain maize, leek and pea) and silage maize, as well as for green manure and catch crops (fodder radish, yellow mustard, winter rye, oats, Italian ryegrass, English ryegrass, common vetch and tagetes) were collected from scientific and grey literature. For the Netherlands, own data from Wageningen University & Research (De Haan et al., 2018, Haagsma, 2018, Hoek et al., 2005) were extracted from the database. Besides that, literature research was oriented to find data from other European countries with similar climatic conditions and crop yields as the Netherlands such as Denmark for example.

In total, data of 11 publications (4 for arable, 8 for catch crops and green manures) were integrated to create the database analysed further in this report. Per crop a minimum number of datapoints of n=4 was respected in principle. For English ryegrass and tagetes as well as for the belowground biomass of arable crops only 2 datapoints per crop could be collected in the given timeframe. The largest dataset was collected for fodder radish with 44 datapoints.

In addition to the biomass value, the following information about the experiments was collected, because it was thought to influence biomass growth, potentially. These aspects are:

- country where experiment took place,
- soil type,
- pre-crop,
- N fertilisation rate,
- seeding rate,
- growing period,
- trial duration in years and
- sampling depth for belowground biomass data.

An overview of these literature sources is given in Table 2.

2.2 Treatment of literature data

Most of the collected data were expressed in dry biomass. Units were all transferred into the common unit of kg ha^{-1}. Dry matter biomass was transferred to organic matter assuming 90% of organic matter in the dry matter (for all crops, below and aboveground). Organic matter [kg ha^{-1}] was transferred to Effective Organic Matter (EOM) by multiplying with humification coefficients as recommended by the current Dutch method (Handboek Bodem en Bemesting, 2018b, c, see Table 3).

Conijn and Lesschen (2015) compared humification coefficients from various sources, from which it can be concluded that differences in HC's have only been reported for belowground biomass. For aboveground biomass the authors concluded that most literature refers back to the same source. Overall, it was concluded that the values given in table 3 are still valid and useful for the calculation of EOM. Larger need for update was expected for biomass values and therefore the focus of this investigation was put there.

Table 2 Overview of literature integrated in the database on biomass of crop residues and catch and green manure crops

Reference	Crop	Plant part (aboveground, belowground, both)	Country	Soil	Pre-crop	Aim of study	Number of years	other
Bolinder et al., 2015	potato, sugar beet	belowground	literature review	n.a.	n.a.	review field measurements of belowground biomass of sugar beet and potato	n.a.	
De Haan et al., 2018	fodder radish	aboveground	NL	sandy	spring barley	2 treatments: low and high organic matter input with manure	4	
	black oat				spring barley/ potato		3	
	English ryegrass				Pea		1	
	Tagetes				Pea		1	
De Haan et al., 2018	Potato	aboveground	NL	sandy	Maize	compare different OM amendment regimes: mineral, low and high animal manure	6	
	Leek				Pea			
	sugar beet				spring barley			
	Pea				Potato			
	spring barley				Leek			
De Ruijter, 2012	fodder radish	aboveground	NL	sandy	Triticale	evaluating perspective for compost and biogas production from catch crop biomass	1	
Haagsma, 2018	fodder radish, yellow mustard, phacelia, winter rye, black oat, common vetch	aboveground	NL	sandy/ clay	pea/ potato/ spelt/ green beans		3	
Hoek et al., 2005	fodder radish, yellow mustard, winter rye, Italian ryegrass, common vetch	aboveground	NL	clay/ peat	none/ cumin		1	
Hu et al., 2018	spring barley, winter wheat	belowground	DK	loamy sand	n.a.	identify most reliable method to estimate belowground biomass of cereals and catch crops based on dataset from field measurements in DK, organic and conventional fields	n.a.	
Li et al., 2015 cited by Hu et al., 2018	fodder radish, Italian ryegrass	aboveground	DK	loamy sand	Cereal	n.a.	n.a.	organic

Mattsson et al., 1991 cited by Bolinder et al., 2015	potato	belowground	SE	n.a.	n.a.	n.a.	n.a.	
Mueller et al., 2001	hairy vetch, common vetch, winter rye, Italian ryegrass	aboveground	DK	sandy loam	barley (straw incorporated)	study N fixation potential of green manure crops	2	
Mutegi et al., 2011 cited by Hu et al., 2018	fodder radish	aboveground	DK	loamy sand	Cereal	n.a.	n.a.	conventional
Steen and Andrén, 1990 cited by: Bolinder et al., 2015	potato	belowground	SE	n.a.	n.a.	n.a.	n.a.	treatment: low versus high C content soil
Sleutel et al., 2007	potato, sugar beet, winter wheat, grain and silage maize	aboveground	BE (Flanders)	n.a.	n.a.	identify shifts in management practices in the past that have resulted in soil carbon loss	n.a.	
Thorup-Kristensen et al., 2001	phacelia, hairy vetch, winter rye, fodder radish, oat, Italian ryegrass	aboveground	DK	sandy loam	Pea	study relation between root growth and N uptake, organically managed fields only	2	
Van Dam, 2006	winter rye, fodder radish	aboveground	NL	coarse sand (pot, outdoors)	Na	study leaf dynamics and assimilation over growing period	n.a.	
Van Noordwijk et al., 1994 cited by Bolinder et al., 2015	sugar beet	belowground	NL	n.a.	n.a.	n.a.	n.a.	
unpublished cited by Hu et al., 2018	fodder radish	aboveground	DK	n.a.	Cereal	n.a.	n.a.	conventional

Table 3 Overview of applied humification coefficients to derive Effective Organic Matter (EOM) from Organic Matter; according to Handboek Bodem en Bemesting, 2018

	Catch Crops	Arable Crops
Aboveground	20%	20 % (30% for cereals)
Stubble (potato and cereals)	n.a.	20% (potato), 30% (cereals)
Belowground	35%	35%

For arable crops some studies (De Haan et al., 2018) did not measure belowground biomass but used a crop specific assumption concerning the belowground biomass yield. These were treated in a way that they were not integrated in the dataset for belowground biomass only but well compared with the values for total residue EOM delivery as indicated in the current method (PAGV, 1989 in Handboek Bodem en Bemesting, 2018c).

Average EOM input to the soil with crop residues was calculated per crop species based on all collected data points. This was done separately for aboveground-, belowground and total biomass. These averages therefore do not take into account effects of soil type, pre-crop or N fertilisation nor cultivation duration.
These averages were compared with currently used EOM estimations (PAGV, 1989 in Handboek Bodem en Bemesting, 2018c). However, for most catch crop and green manure species only total EOM input is available, and it is not split up in above- and belowground biomass.

It has to be noted that for data on oat grown as catch crop, data for two different species, *Avena sativa* and Japanese oat (also called Black oat), *Avena strigosa*, were collected. The statistics indicated for “oat” refer thus to both together.

2.3 Derivation of three plant development classes for catch crops

Variation of data around the mean was large. This is not surprising in particular for catch crops and green manure crops since they can reach quite different biomass development depending on how early they were seeded in the end of summer and the weather conditions throughout the growing phase for example (Hashemi et al., 2013 and Komainda et al., 2016). It was therefore decided to propose three classes with associated EOM [t ha^{-1}] input to the soil organic matter: bad, good and very good plant growth development. For practical applications, it seems to be useful to use pictures as a helpful tool for distinguishing between crops which are poorly, normally or well developed (Comifer, 2011).

Since most of the data is spread relatively equally in a wide range around the average biomass value per crop species, we tested the following rule for setting crop specific class limits: for the lower limit between bad and good: average biomass-30% and for the upper limit between good and very good: average biomass +30%. This led to a datapoint distribution into the three classes which was seen as realistic. Realistic in this sense means that each class represents at minimum 13% of the datapoints per crop species and that for most crop species a distribution over the classes is reached with around 50% of the datapoints laying in the middle class (“good”) and each 25% of the datapoints in the classes “very good” and “bad”.

3 Results

3.1 Green manures and catch crops

In particular for fodder radish and yellow mustard a relatively high number of data points could be collected from literature (44 and 33 for aboveground biomass and 21 and 12 for belowground biomass respectively). For all species where more than 2 data points were available for the average calculation, the variation of the values around the mean is large (see Figure 1 and Figure 2).

A comparison with values from the current organic matter balance method is only possible for Italian and English ryegrass since for other crops the current organic matter balance method does not provide any values split up in above- and belowground biomass. For Italian ryegrass aboveground biomass, the current value is 660 kg ha^{-1}. It is thereby only 10% higher than the average aboveground biomass of 600 kg ha^{-1} calculated from literature data (see Figure 3 and Table 1). For English ryegrass the current value for aboveground biomass is 560 kg ha^{-1}, which is 25% higher than the average value of 450 kg ha^{-1} calculated from literature data (see Figure 1). Concerning belowground data (see Figure 2), the current values are 420 kg ha^{-1} and 600 kg ha^{-1} respectively for Italian ryegrass sown in stubble and English ryegrass sown under a cover crop (see Table 1). For Italian ryegrass the current value is thereby about 27% lower than the literature average. For English ryegrass the current value is 15% lower than the literature average.

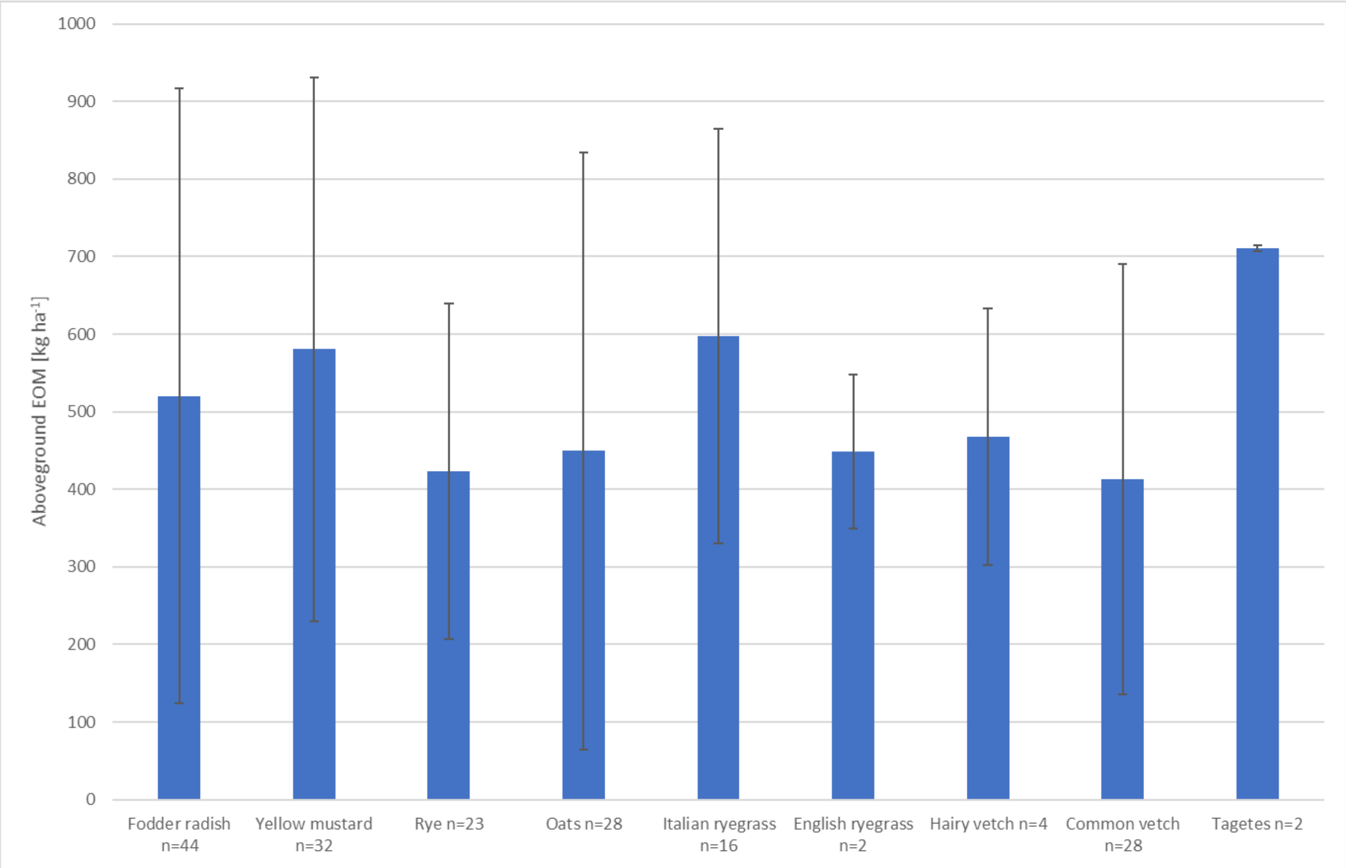

Figure 1 Average aboveground Effective Organic Matter (EOM) input to the soil of different catch crops and green manure species. “n” indicates the sample size that the average was calculated of; error bars indicate standard deviation.

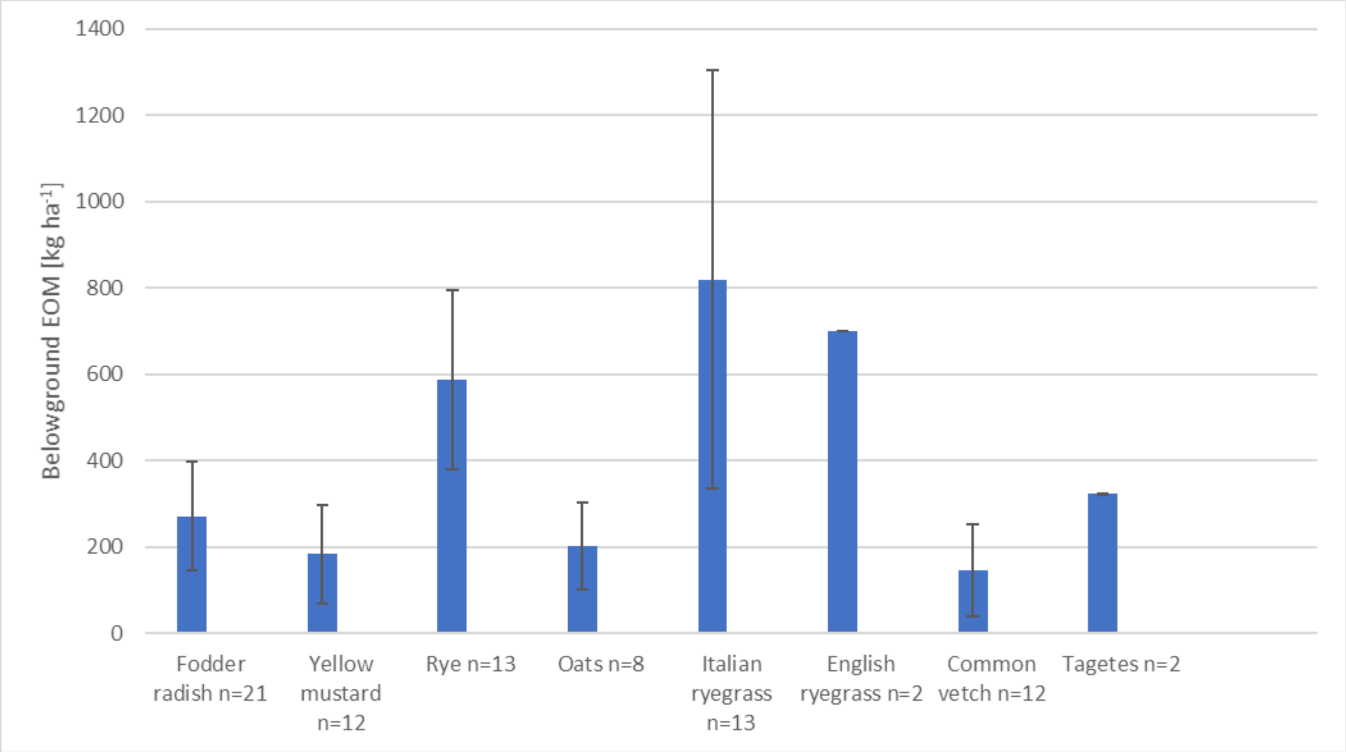

Figure 2 Average belowground Effective Organic Matter (EOM) input to the soil of different catch crops and green manure species. “n” indicates the sample size that the average was calculated of; error bars indicate standard deviation

In Figure 3 the total Effective organic matter input with catch crops and green manure crops as given by the current organic matter balance method is compared with the sum of the average for aboveground and belowground EOM as calculated from literature data. Overall, the differences between both are not large. Besides for Italian ryegrass grown in stubble the difference is smaller than 20% (see Figure 3). For Italian ryegrass grown in stubble the current value is about 30% lower than the literature average. This is mostly due to a smaller belowground biomass in the current method. However, it has to be noted that the current method makes a difference between Italian ryegrass sown under a cover crop and sown in stubble whereas from literature we were not able to retrieve this information. For oats grown as catch crops there is currently no recommendation given.

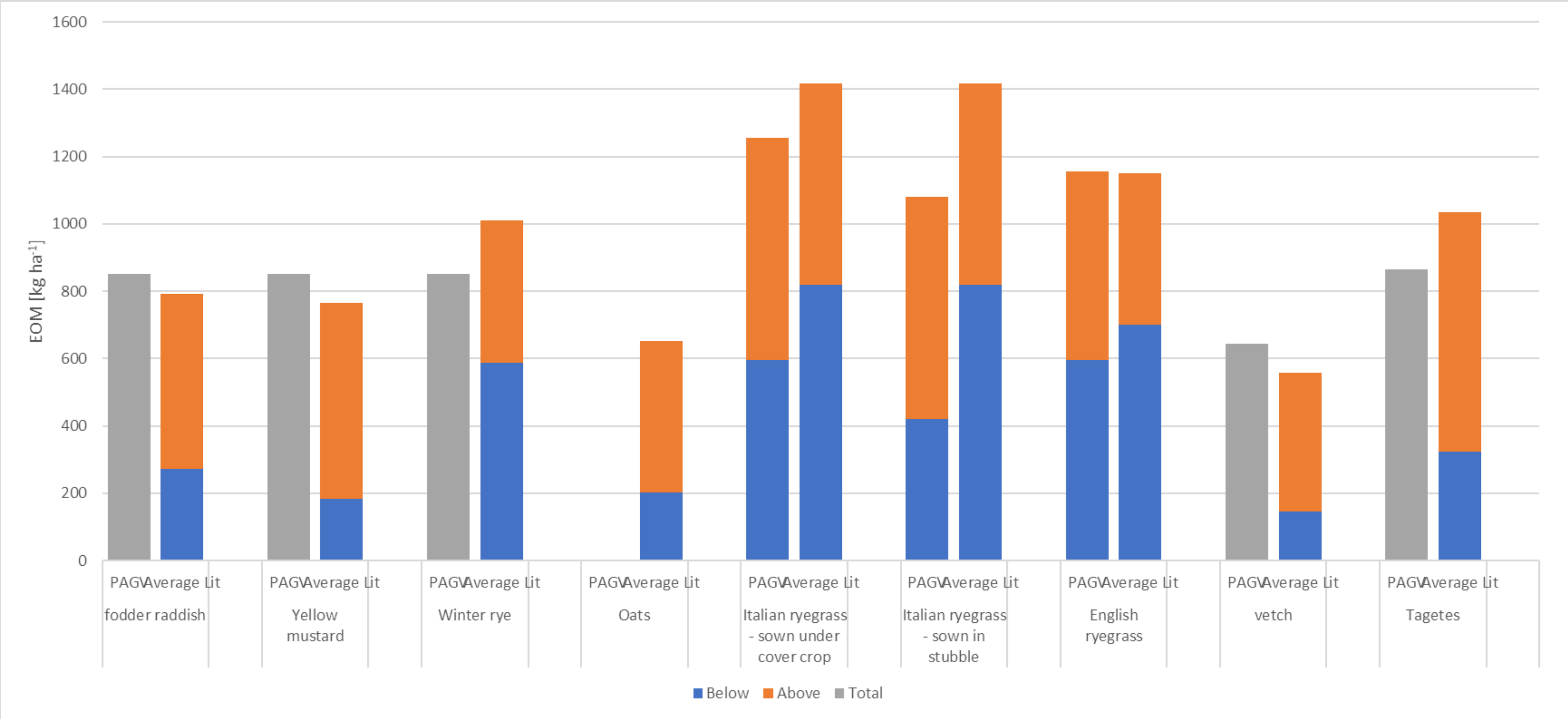

Figure 3 Comparison of average total Effective Organic Matter (EOM) input to soil of different green manure and catch crop species between reviewed literature data average (blue for belowground, orange for aboveground) and PAGV, 1989 recommended values (current Dutch humus balancing method, grey bars), values split up in below- and aboveground from the current values are only available for Italian and English ryegrass; for oats grown as catch crop there is currently no recommendation available; the values from literature for Italian ryegrass are displayed here twice as PAGV (1989) differentiates between “sown under cover crop” and “sown in stubble” but this information is not available in literature

3.2 Arable crops

For aboveground biomass of potato, leek, sugar beet, pea and spring barley around 12 data points per crop species were collected. For winter wheat, grain and silage maize only one publication was reviewed due to limited availability of data (see Figure 4). Belowground data were more difficult to find in literature and due to that only two to three (potato) data points could be collected (see Figure 5).

Compared to catch crop data we observed much larger differences between current values and literature averages for aboveground EOM. The largest differences can be observed for silage maize and pea: for silage maize the current value is about 5 times smaller than the literature value from Sleutel (2007) and for peas the current value is also less than half of the literature average. However, to have (statistically) reliable results that allow well-founded conclusions, more data would be needed. Spring barley is the only crop where almost no difference between the current recommendation and the literature average for aboveground biomass was identified (see Figure 4).

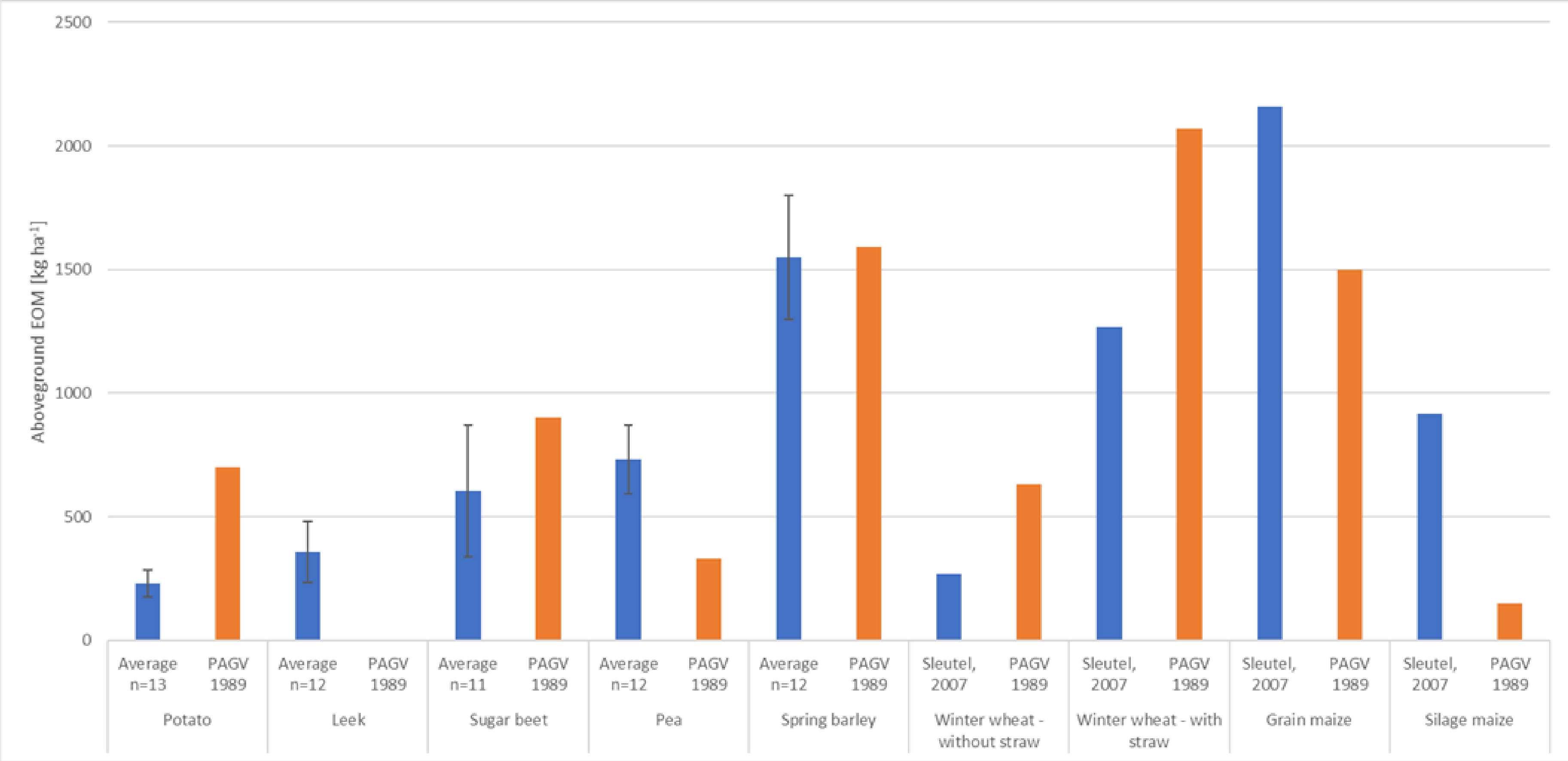

Figure 4 Average aboveground Effective Organic Matter (EOM) input to the soil with residues of different crop species. “n” indicates the sample size that the average was calculated of; error bars indicate standard deviation; the orange bars indicate the current value in Dutch organic matter balancing (PAGV 1989); for winter wheat, grain and silage maize only one value for aboveground biomass was extracted from literature; for leek aboveground biomass there was not value from PAGV (1989) available

For belowground EOM of crop residues, differences between current values and literature averages amount up to almost 50% for sugar beet (current value higher) (see Figure 5). Only for winter wheat the difference is very small with the current recommendation being 8% lower than the literature average.

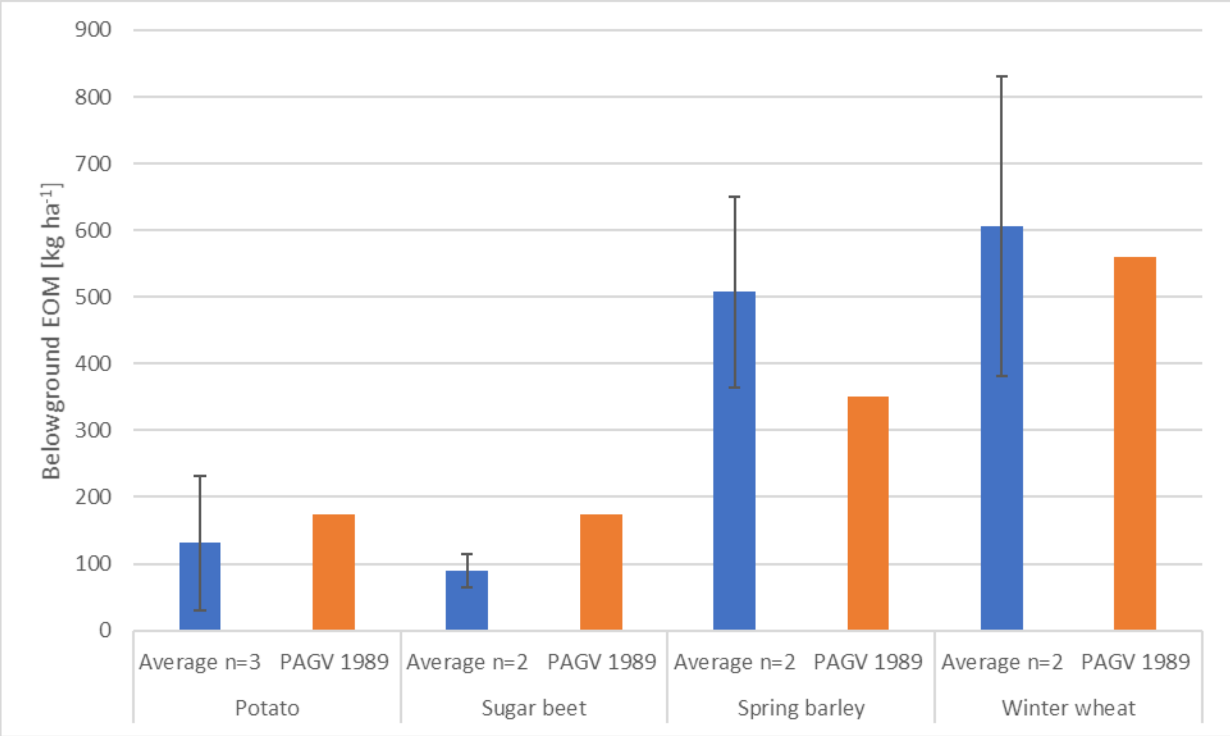

Figure 5 Belowground Effective Organic Matter (EOM) input to the soil with residues of different crop species. “n” indicates the sample size that the average was calculated of; error bars indicate standard deviation; the orange bars indicate the current value in Dutch humus balancing, for potato and sugar beet one of the values collected from literature already represents an average over several literature value

In Figure 6 a comparison was made between average total EOM values from the following sources:

- data from De Haan et al. (2018) only,
- an average based on all other literature data and
- the data in the current system (PAGV, 1989).

The data from De Haan et al. (2018) were separately considered, because this publication dominantly contributed to the aboveground biomass data, whereas the study did not measure belowground biomass.
For potato there is no large difference between the average of De Haan et al. (2018) and other literature data. However, the aboveground part, as can also be seen in Figure 4, is about three times higher than that of current values.
For leek the current data do not provide values split up in above- and belowground biomass. The current values for the case that residues are ploughed in is of a similar range than the literature averages.
For sugar beet, the average of the data of De Haan et al. (2018) is almost half as that of both the rest of the literature as well as the current values. Therein, the average belowground biomass was only half that of the average of De Haan et al. (2018) data whereas for the aboveground it was about the double. According to data from over 100 fields with sugar beets that have been sampled in the period 2006-2015, the average amount of effective organic matter was 1219 kg EOM per ha (983 kg aboveground and 236 kg belowground; IRS, 2018). This is only slightly lower than the current value of 1275 kg EOM per ha, which can be explained by lower amount

of biomass in the leaves of the newer varieties and differences in the harvesting method.
For pea and spring barley the average based on data from De Haan et al. (2018) and the current recommendation are similar. From other literature for these species only data about the belowground biomass of spring barley were collected: this was about 25% higher in average based on the other literature compared to the current recommendation.
The data for winter wheat show similar values as today's recommendations for belowground but not for aboveground biomass. Independently of whether straw is harvested or left as residues, literature data (which only comprises of data from Sleutel, 2007) indicate much smaller EOM input of aboveground residues than the current values.

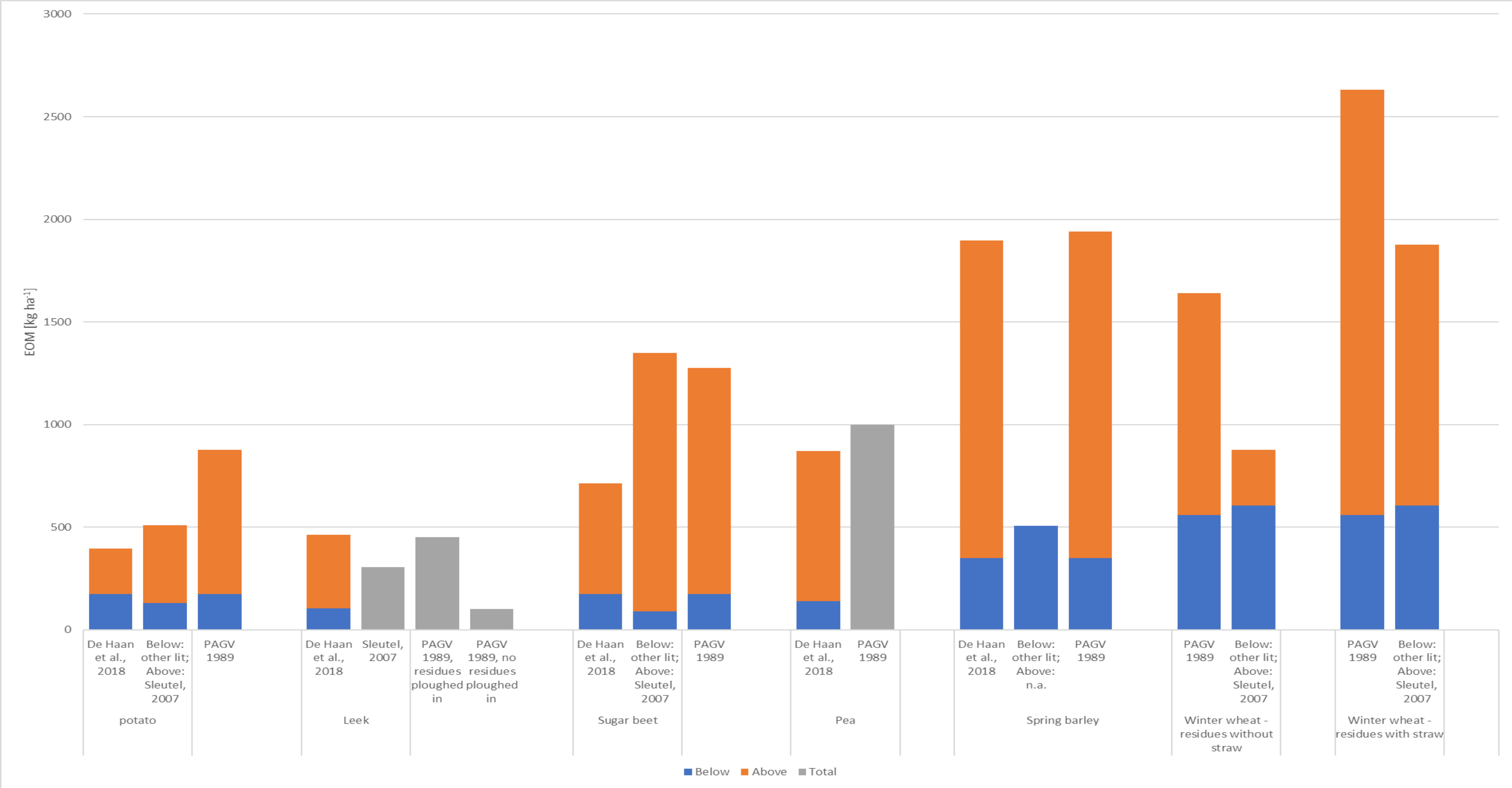

Figure 6 Comparison of average total Effective Organic Matter (EOM) input to soil with residues of different crop species between data from De Haan et al., 2018, other literature reviewed (thus not including De Haan et al., 2018 or Sleutel, 2007) and PAGV, 1989 recommended values (current Dutch humus balancing method); blue for belowground, orange for aboveground data and grey if only total was available; data from De Haan et al., 2018 did not measure belowground biomass but assumed fixed values (blue bars in graph); for aboveground biomass of spring barley no other data than De Haan et al., 2018 was available

3.3 Variation in Green manure/ Catch crop biomass development

The collected data about biomass of catch crops and green manure crops show a large variation as shown above by large standard deviations. We therefore investigated further if it makes sense to offer farmers EOM values for three different (expected) crop development qualities (bad, good and very good development) and if yes, which values should be used for those development classes.

3.3.1 Analysis of variation

In a first step we looked at the frequency of how many of our datapoints fall into each class by calculating bad, good and very good development as: mean EOM over data collected +/- 30%. This was done separately for aboveground biomass (Table 4), belowground biomass (Table 5) and total biomass (Table 6). Results show a balanced distribution of datapoints (numbers in brackets in tables listed before) over the three different development classes. For most about 50% lay in the middle class of "good" development and the other half of datapoints is shared between "bad" and "very good" development.

Table 4 Classification Scheme for effective organic matter supply by aboveground biomass of different green manure and catch crop species according to whether biomass development is "bad", "good" or "very good"; class thresholds represent the average EOM supply by aboveground biomass [EOM kg ha^{-1}] +/- 30%; number in brackets indicate the number of datapoints of the underlying dataset falling into this class

	Crop biomass development		
Crop	Bad	Good	very good
Fodder radish	<360 (22)	360 to 680 (9)	>680 (13)
Yellow mustard	<410 (13)	410 to 750 (10)	>750 (9)
Winter rye	<300 (6)	300 to 550 (10)	>550 (7)
Oats	<310 (13)	310 to 580 (10)	>580 (5)
Italian ryegrass	<420 (4)	420 to 780 (8)	>780 (4)
Common vetch	<290 (10)	290 to 540 (8)	>540 (10)

Table 5 Classification Scheme for effective organic matter supply by belowground biomass of different green manure and catch crop species according to whether biomass development is "bad", "good" or "very good"; class thresholds represent the average EOM supply by aboveground biomass [EOM kg ha^{-1}] +/- 30%; number in brackets indicate the number of datapoints of the underlying dataset falling into this class

	Crop biomass development		
Crop	bad	Good	very good
Fodder radish	<190 (6)	190 to 350 (10)	>350 (5)
Yellow mustard	<130 (3)	130 to 240 (7)	>240 (2)
Winter rye	<410 (4)	410 to 760 (6)	>760 (3)
Oats	<140 (2)	140 to 260 (5)	>260 (1)
Italian ryegrass	<570 (3)	570 to 1,060 (7)	>1,060 (3)
Common vetch	<100 (2)	100 to 190 (8)	>190 (2)

Table 6 Classification Scheme for effective organic matter supply by total biomass of different green manure and catch crop species according to whether biomass development is “bad”, “good” or “very good”; class thresholds represent the average EOM supply by total biomass [EOM kg ha^{-1}] +/- 30%; compared to tables 3 and 4 the number of datapoints falling into that category cannot be indicated since the average was derived by summing up average above- and belowground biomass.

	Crop biomass development		
Crop	Bad	Good	very good
Fodder radish	<550	550 to 1,030	>1,030
Yellow mustard	<530	530 to 990	>990
Winter rye	<710	710 to 1,310	>1,310
Oats	<460	460 to 850	>850
Italian ryegrass	<990	990 to 1,840	>1,840
Common vetch	<390	390 to 730	>730

3.3.2 Proposal on EOM values for three development classes

A proposal for the values of effective organic matter supply by catch crops and green manure crops which differ in biomass development is given in Table 7. These values are based on the data (averages and standard deviations) of aboveground and belowground biomass production from the literature that has been described in the foregoing text (Figure 1 and Figure 2) and could be used for the calculation of the organic matter balance.

The values for EOM from current recommendations (Handboek Bodem en Bemesting (2018b) and (2018c) and PAGV, 1989) are mainly close to the value of “good” crop development. Only for Italian ryegrass the current value would be classified more as “bad” development and the current value for common vetch EOM supply as “very good” development.

Table 7 Proposed values for effective organic matter supply (in kg per hectare) by green manure and catch crop species (entire plant, above- and belowground together) according to whether biomass development is “bad”, “good” or “very good”.

		Crop biomass development	
Crop	**Bad**	**Good**	**very good**
Fodder radish	400	800	1200
Yellow mustard	450	760	1150
Winter rye	700	1000	1300
Oats	250	650	1050
Italian ryegrass	800	1400	2000
English ryegrass	700	1150	1600
Common vetch	300	540	800

In a further step this concept should be further developed by coupling indications on associated management choices such as seeding date and N fertilisation rate to the different classes. This would allow farmers to also use it as a planning tool ahead of the growing season, based on their expected management. This concept is to be seen as a preliminary concept which will need to be further improved and validated with experimental data.

4 Discussion

4.1 Comparison of literature data with current recommendations

With regard to the catch crops, the collected literature data and in consequence the calculated recommendation on a mean EOM input to the soil under "good" crop development (see Table 7) are in line with the current recommendations of the Dutch organic matter balance (Handboek Bodem en Bemesting, 2018c). This means in consequence, seeing the large variation in biomass of the literature data, that cases of bad or very good development are currently not represented in recommendations. The organic matter balance advice system should thus be improved in this direction for catch crops. This insight into the variation of catch crop biomass is the most important achievement of this investigation and should be taken into consideration for further development of the organic matter balance method.
Japanese oat (also called black oat, *Avena strigosa*) became a popular catch crop in recent years in the Netherlands but currently there is no recommendation existing on how to evaluate its contribution to soil organic matter. This recommendation should therefore be developed to improve the crop coverage of the current recommendation system.

For arable crops it was a research aim to find out whether innovations especially in plant breeding over the past decades require an update of EOM values developed in 1989. The literature data analysis shows that differences in above:belowground biomass ratios for some crops might require an update of current values. For all crops the change in ratio would be caused by different aboveground biomass, almost never due to changed belowground biomass, based on data we collected (see Figure 6). Potato data suggests that nowadays aboveground biomass is lower, whereas for sugar beet some literature suggest no change in aboveground biomass (De Haan et al., 2018) and other literature and increased aboveground biomass. However, as will be discussed further below in the following section, a high uncertainty in the method to determine biomass and which plant parts are included can also be a reason behind these differing values.
With respect to cereals, we collected data from spring barley and winter wheat. For spring barley our data does not suggest that the ratio of above:belowground biomass has changed from 1989 to today. For winter wheat it is known that plant breeding led to varieties shorter in straw nowadays. Our data also suggest this but on the other hand the dataset is with only one source too small to take a valid conclusion.
Overall, it has to be noted that a lot of the data about arable crops originate from one publication only (De Haan et al., 2018). It was chosen to focus on catch crops in this study since catch crops are a lot more popularly grown nowadays compared to 1989 suggesting a need for creating a wider data basis. However, literature data would need to be extended to draw better conclusions and uncertainties (explained in following section) would need to be limited.

4.2 Uncertainty in data

The interpretation of data towards conclusions on whether an update of the EOM values of the current organic matter balance method is necessary is difficult due to several uncertainties on literature data. The information and method is not always well documented or if it is documented data with different biomass determination methods are not comparable. In detail this concerns:

- Cereals: in literature it is not always indicated whether straw is incorporated or harvested and thus whether it is included in the figure on aboveground residues or not but also when straw is harvested substantial differences in the EOM value can evolve depending on the mowing height. In practice, mowing height is determined by a number of management decisions as for example whether the soil is stony and conflict between harvester and stones needs to be avoided.

- Sugar beets: for sugar beets practice differs between harvesting the beets with or without their heads. This is often not clearly indicated in literature which of the two methods was applied and corresponds to the aboveground biomass figure. For a future recommendation system both harvesting methods should be given separate EOM values.

Potatoes: for potato aboveground biomass data the specific challenge is to define the appropriate moment in the course of the growing season to determine it. Aboveground plant parts dye off towards the end of the season and it is therefore discussable which point of time in the plant development is the most appropriate to measure aboveground biomass. The moment when biomass was determined is often not documented in literature. For all belowground data another challenge makes the interpretation of data difficult: the sampling depth is not always indicated in literature or sometimes correction methods being based on extrapolation have already been applied to the data.

All in all, there is a large number of uncertainties which make it difficult to draw reliable conclusions based on the collected literature data. With own experiments where above mentioned aspects are well documented and controlled, the database could be improved.

4.3 Lack of data and limitations of this study

Seeing the large variation in biomass data it will be important to extend the database we collected in the framework of this project by more datapoints. In particular, data about belowground biomass are often lacking in research publications. Since we prioritized catch crops, not all available data about biomass of residues from arable crops could be integrated in the analysis.

4.4 Alternative concepts to determine carbon input by crop residues to soil

The amount of biomass produced by harvest residues is often not determined and it can be questioned if it can be derived from crop yield or other factors such as the variety of the crop, soil type, the fertilisation level, management factors, etc. For that reason, several studies have been performed to investigate the possibilities to estimate the amount of crop residues (aboveground and belowground) at the basis of the harvested product (yield) or management. Two different concepts are described below.

4.4.1 Allocation method

The carbon allocation method as described by Bolinder et al. (2007) was developed in Canada. The method differentiates between four different carbon fractions of a crop: the harvest good, aboveground biomass (excl. harvest good), belowground biomass (excl. harvest good for root crops) and the “extra-root” Carbon. The “extra-root” Carbon fraction includes root exudates and other material from root-turnover, commonly referred to as “rhizodeposition” (Bolinder et al., 2007). For each of these fractions a coefficient is calculated based on field experiment data. With formulas combining these coefficients the carbon input to the soil of each of these fractions can be calculated. The only input value is then the crop yield.

The calculation of allocation coefficients by (Bolinder et al., 2007) is based on publications of shoot:root ratios of field experiments in Canada and the U.S. In total, for arable crops, 29 field experiments published post 1970 have been evaluated. In most of the experiments, crops were fertilized according to fertiliser recommendations and sites were situated on various soil types. Several authors adapted the method by calculating allocation coefficients adapted to different contexts (Wiesmeier et al., 2014, IPCC, 2006 cited by Bolinder et al., 2015)). Wiesmeier et al. (2014) calculated, based on experimental data and agricultural statistics, coefficients for Bavaria for the time periods 1951 to 1955 as well as 1995 to 2010 separately. The results support our hypothesis that biomass growth and C allocation between above- and belowground fractions changed with the evolution in plant breeding over the past decades. They calculated a total increase in carbon input to the soil with crop residues of up to 188% (root, forage and leguminous crops) from the period 1951 to 1955 to the period 1995 to 2010. Also allocation coefficients changed over the same time by up to 87%. In tendency, relative contribution of crop yields and belowground biomass to total net plant productivity increased (cereals) or stayed the same (root, forage and leguminous crops) whereas the contribution of aboveground biomass decreased (Wiesmeier et al., 2014). Most authors working with an allocation method make use of the assumption that carbon input by root exudates is "65% of root biomass C" (based on Kuzyakov and Domanski (2000) and Kuzyakov and Schneckenberger (2004) cited by Bolinder et al., 2007)). Besides shoot:root ratio and the relative carbon exudation, crop-specific harvest indexes build the basis for the calculation of allocation coefficients.

Compared to the current humus balance method of the Netherlands, the allocation coefficient approach has the advantage that farmers only need to know their crop yield to calculate carbon input to the soil by different plant fractions. With this method carbon input to the soil is yield specific and therefore does not just indicate one fixed value but corrects for crop development by taking into account the yield level. However, under the scenario that allocation factors would be introduced in the Netherlands, research will need to be done to derive allocation coefficients adapted to conditions in the Netherlands. Since for catch crops and green manures there is normally no harvest and thus no figure on crop yield, the method and its advantage are not applicable to catch crops and green manures.

The allocation coefficient approach is criticized by other researchers (Hu et al., 2018) for being too static. The authors argue that shoot and root biomass growth reacts differently to environmental and management factors such as Nitrogen fertilisation resulting in different shoot:root ratios at the end of the growing period (Hu et al., 2018).

4.4.2 Fixed values for belowground biomass

Hu et al. (2018) carried out a "leave one out cross validation" with data from longterm field experiments in Denmark to check performance of different models (including the allocation method of Bolinder et al., 2007) to predict belowground biomass of cereals, catch crops and weeds. The analysis also tested for the impact of different environmental and management factors on the belowground biomass. According to the cross validation, the root biomass of cereals can be predicted most reliably with fixed biomass values depending on year, farming system (conventional versus organic) and species. Leaving the year out was predicting almost as reliably. Models based on allometric ratios were poorer in their prediction. The results for catch crops revealed that farming system (conventional versus organic) was also the most important determining factor for belowground biomass (Hu et al., 2018).

The analysis of Hu et al. (2018) also reveals that shoot biomass of cereals is strongly influenced by Nitrogen fertilisation whereas belowground biomass is far less influenced by it. This is thus supporting the hypothesis that belowground biomass cannot be well estimated based on aboveground biomass with fixed allometric ratios. Hu et al. (2018) therefore concluded that belowground biomass of cereals and catch crops may be better estimated with fixed values (crop species and farming system specific) than with allocation methods based on crop specific root:shoot ratios.

This conclusion means for the revision of the Dutch organic matter balancing system that the basic principle of using fixed values still seems to be a valid approach (at least for the belowground fraction). Since the values for crop residues at the organic matter balance are already crop species-specific, only the values but not the principles of the method need to be revised. However, for a lot of crops the current database of fixed values only provides indications on total biomass, not split up in above- and belowground. Hu et al. (2018) remark themselves the same limitation that we also encountered for this study: databases on belowground biomass data are not large enough to draw well justified conclusions. Therefore, the perspective of sticking to fixed values but

improving the underlying database in particular with data from belowground biomass sampling, is supported. It needs to be kept in mind that the cited study only analysed data on cereals and catch crops and it would therefore need to be researched of fixed values are also performing well for root crops.
In conclusion, for the Dutch humus balance system revision, the results of Hu et al. (2018) can be interpreted so that a revision of basic principles with crop specific fixed values is not necessary. On the other hand, sampling of belowground biomass under nowadays conditions in the Netherlands seems necessary to update fixed values. The allocation approach stays interesting from the point of view that using yield data only as an input to still relatively well estimate other biomass fractions, is easy and intuitively to use for farmers.

4.4.3 Estimating aboveground biomass with sensor technologies

Another approach which has evolved in recent decades and is under constant development is the measurement of crop biomass with the help of sensing technologies, namely spectral sensors. Sensors can be attached to drones and collect data while flying over fields. In recent years several authors have published results which show that aboveground biomass can be predicted accurately by combining different multi- and hyperspectral information and plant height measurements in linear regression models (Näsi et al., 2017 and Yue et al., 2017). However, limitations of these methods are that only the aboveground part of crops can be estimated and that investments in technology are required. Future developments in improved prediction accuracy and decreasing prices for technologies are worth to be followed.

4.4.4 French classification system for different aboveground plant development of catch crops

In France a simple approach has been developed to allow farmers to estimate the aboveground biomass of catch and green manure crops. In this method, photos are providing the bases to estimate the biomass depending on how good the aboveground growth visually looks like.
The tool was developed to assist farmers in estimating the aboveground biomass fraction of their catch or green manure crop in a very easy to apply and intuitively to use way (Comifer, 2011). The method was published in 2011 by a consortium of different applied research and consulting bodies. The guidance document gives farmers a collection of photos at hand which are crop specific. For most crops for each development stage a photo taken from the side including a measurement of crop height as well as a photo from above are provided. The range of species as well as the range of aboveground biomass are displayed in Table 8.

Table 8 Overview on the number of classes per crop group and the range of aboveground biomass covered with photo description by the French method (Comifer 2011); it has to be noted that biomass is not expressed as EOM as in all other figures but in dry matter

Species or crop group	range aboveground biomass [t DM ha-1]	number of photos per species/ crop group
White mustard	0.5 to 4	6
Fodder radish	0.5 to 4	5
Phacelia	0.5 to 3	5
Grasses/ cereals (incl photos for Italian ryegrass, winter rye, oat)	0.5 to 4	6
Legumes (incl. photos for Common and purple vetch, lentil, forage pea, faba beans	0.7 to 4	6
Mixes (incl. photos for raddish+vetch, oat+vetch, multi-species mix)	1.5 to 5.5	5

The method was derived in a very un-academic way simply by aiming to represent a wide range of aboveground biomass development in pictures (up to 4 t DM ha^{-1} for most species). This was realized by taking photos in different trials and demonstration fields where dry matter biomass was measured. Photos represent an approximate value of aboveground biomass (see Figure 7).

Figure 7 Example photos of the Comifer method from France (Comifer 2011); both photos show white mustard and represent the lowest depicted aboveground biomass (0.5 t DM (=MS) ha-1) and the highest (4 t DM (=MS) ha-1)

Similar pictures could be used as a basis for the estimation of the EOM supply by catch crops in the Netherlands, but then the values of the dry matter supply should be transferred into effective organic matter (EOM), by multiplying with organic matter contents of biomass (about 90%) and humification coefficients of above- and belowground biomass (ranging from about 0.2 – 0.35).

5 Conclusions and recommendations

5.1 Conclusions

Currently used values for the EOM supply by catch crops are in line with values from literature, but represent well established catch crops only. However, our data suggest that in practice large variations around average values of catch crop biomass occur in dependence of sowing date, etc.

For arable crops, the collected data on biomass production and associated amounts of (effective) organic matter are quite different from the current recommendations, but not enough data are available for a change. A more extensive evaluation appears to be worthwhile.

Based on several review articles, it is difficult to make an accurate estimation of crop residues at the basis of crop yield. Other management factors, like the fertilisation level, may have a large effect on amount of crop residues, in particular the above:belowground biomass ratio.

At the basis of a quick scan of humification coefficients in literature, it can be concluded that humification coefficients for belowground biomass vary. For aboveground residues and catch crops, Conijn and Leschen (2015) concluded that the investigated literature sources all go back to the same source and that therefore experimental research on this topic is needed.

5.2 Recommendations

It is recommended to replace current values of effective organic matter supply by catch crops on the organic matter balance by values which depend on the (foreseen) development of the catch crop (bad, good or very good). That should be taken into account in an improved version of the organic matter balance:

- If the organic matter balance is used as a planning instrument, an estimation of the foreseen development of catch crops (bad, good or very good) can be made at the basis of the planned sowing dates: a late sowing date will lead to a bad crop development, an appropriate sowing date to a good crop development and an early sowing date to a very good crop development. The proposed values of table 7 can be used for the organic matter balance as a preliminary proposal which should be further improved and validated with more (experimental) data.
- If the organic matter balance is used as a monitoring tool, the actual biomass production of catch crops could be taken into account. Pictures maybe helpful to be able to distinguish between poorly, normally or well developed catch crops. A similar method is in use in France (Comifer, 2011). More advanced methods to estimate the biomass production, could be based on sensing technologies.

Because a limited amount of data about biomass of and organic matter supply by crop residues was found within the scope of this study, it is not recommended to change the current values. A more extensive evaluation is recommended.

It is recommended to take the following steps in further research:

- Step 1: Identify (management) factors that have the most important impact on biomass development of arable crop residues and catch crops;
- Step 2: build up a better database on biomass of crops (experiments designed to test for and quantify influence of management factors identified in step 1);

- Step 3: Link the quantification of the influencing management factors from step 2 to a class system giving recommendations on specific EOM input associated to a set of management choices planned or made (monitoring purposes).

Based on the review of humification coefficients from literature by Conijn and Lesschen (2015), it can be concluded that not enough experimental data on this topic is available. This appears to be a good reason to carry out additional work on this topic.

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Annex 1

Table 1: Table published online as advice to farmers on organic matter balance calculation, from: Handboek Bodem en Bemesting (2018b)

Tabel 9.1. Aanvoer verse organische stof (OS) en effectieve organische stof (EOS) uit gewasresten

Gewasrest	OS (kg/ha)	H.C.[1] (fractie)	EOS (kg/ha)
Blauwmaanzaad	3475	0,33	1150
Bruine boon (incl. loof)	2870	0,23	650
Consumptieaardappel	4000	0,22	875
Cichorei	3500	0,22	775
Conserve-erwt	4570	0,22	1000
Grasland, eenjarig	4000	0,29	1175
Grasland, tweejarig	8000	0,32	2575
Grasland, driejarig	12000	0,33	3975
Graszaad, 1e jaars Engels raaigras	6000	0,29	1750
Graszaad, 2e jaars Engels raaigras	7150	0,30	2150
Haver, stro afgevoerd	5000	0,31	1570
Haver, stro achtergelaten	8000	0,31	2470
Karwij	4000	0,32	1275
Knolselderij (incl. loof)	4150	0,24	1000
Koolzaad	3000	0,33	975
Korrelmaïs	7000	0,31	2175
Lelie	1850	0,30	560
Luzerne, eenjarig	3000	0,45	1350
Luzerne, tweejarig	5000	0,41	2050
Pootaardappel	4400	0,22	955
Schorseneer	2400	0,25	600
Snijmaïs	2000	0,34	675
Spinazie	1285	0,23	300
Stamslaboon (incl. loof)	2870	0,23	650
Suikerbiet (incl. kop en blad)	6000	0,21	1275
Spruitkool (incl. stam)	6700	0,30	2000
Triticale	5000	0,31	1570
Tulp (excl. strodek)	1700	0,30	505
Vezelvlas	300	0,33	100
Winterpeen	2400	0,29	700
Wintergerst, stro afgevoerd	5000	0,31	1570
Wintergerst stro achtergelaten	7600	0,31	2350

Gewasrest	OS (kg/ha)	H.C.[1] (fractie)	EOS (kg/ha)	na 5 jaar[2] (kg/ha)	na 5 jaar[2] (fractie)	na 10 jaar[2] (kg/ha)	na 10 jaar[2] (fractie)	C/N
Blauwmaanzaad	3475	0,33	1150	325	0,09	205	0,06	
Bruine boon (incl. loof)	2870	0,23	650	155	0,05	95	0,03	
Consumptieaardappel	4000	0,22	875	200	0,05	125	0,03	36
Cichorei	3500	0,22	775	180	0,05	110	0,03	
Conserve-erwt	4570	0,22	1000	230	0,05	145	0,03	15
Grasland, eenjarig	4000	0,29	1175	310	0,08	195	0,05	24
Grasland, tweejarig	8000	0,32	2575	720	0,09	455	0,06	24
Grasland, driejarig	12000	0,33	3975	1125	0,09	715	0,06	23
Graszaad, 1e jaars Engels raaigras	6000	0,29	1750	465	0,08	290	0,05	45

de bodem.

Table 2: Table published online as advice to farmers on organic matter balance calculation, from: Handboek Bodem en Bemesting (2018c)

Gewasrest	OS (kg/ha)	H.C.[1] (fractie)	EOS (kg/ha)	na 5 jaar[2] (kg/ha)	na 5 jaar[2] (fractie)	na 10 jaar[2] (kg/ha)	na 10 jaar[2] (fractie)	C/N
Tulp (excl. strodek)	1700	0,30	505	135	0,08	85	0,05	37
Vezelvlas	300	0,33	100	30	0,09	20	0,06	25
Winterpeen	2400	0,29	700	185	0,08	115	0,05	28
Wintergerst, stro afgevoerd	5000	0,31	1570	430	0,09	275	0,05	75
Wintergerst stro achtergelaten	7600	0,31	2350	640	0,08	405	0,05	75
Winterrogge, stro afgevoerd	4800	0,31	1500	410	0,09	260	0,05	75
Winterrogge stro achtergelaten	8200	0,31	2520	685	0,08	430	0,05	75
Wintertarwe, stro afgevoerd	5200	0,32	1640	450	0,09	285	0,05	75
Wintertarwe stro achtergelaten	8500	0,31	2630	720	0,08	455	0,05	75
Witlofwortel	2625	0,23	600	140	0,05	85	0,03	30
Zaaiui	1275	0,24	300	70	0,06	45	0,03	30
Zetmeelaardappel	3700	0,22	815	190	0,05	115	0,03	36
Zomergerst, stro afgevoerd	4200	0,31	1310	360	0,09	225	0,05	75
Zomergerst stro achtergelaten	6300	0,31	1940	530	0,08	335	0,05	75
Zomertarwe, stro afgevoerd	5200	0,31	1630	450	0,09	285	0,05	75
Zomertarwe stro achtergelaten	8400	0,31	2590	705	0,08	445	0,05	75

[1] H.C. = humificatiecoëfficiënt: de fractie die één jaar na toediening van het vers organisch materiaal nog over is in de bodem.
[2] De hoeveelheid die 5 en 10 jaar na toediening van het vers organische materiaal nog over is in kg per ha en als fractie van de beginhoeveelheid.

Zomergerst, stro afgevoerd	4200	0,31	1310
Zomergerst stro achtergelaten	6300	0,31	1940
Zomertarwe, stro afgevoerd	5200	0,31	1630
Zomertarwe stro achtergelaten	8400	0,31	2590

[1] H.C. = humificatiecoëfficiënt: de fractie die één jaar na toediening van het vers organisch materiaal nog over is in de bodem.

Groenbemester[1]	OS (kg/ha)	H.C.[2] (fractie)	EOS (kg/ha)	na 5 jaar[3] (kg/ha)	na 5 jaar[3] (fractie)	na 10 jaar[3] (kg/ha)	na 10 jaar[3] (fractie)	C/N
Bladrammenas	3800	0,23	875	205	0,05	130	0,03	20
Gele mosterd	3800	0,23	875	205	0,05	130	0,03	20
Bladkool	3600	0,24	850	205	0,06	125	0,03	24
Engels raaigras	4250	0,27	1155	295	0,07	185	0,04	23
Italiaans raaigras	4200	0,26	1100	275	0,07	170	0,04	22
Westerwolds raaigras	4000	0,26	1050	265	0,07	165	0,04	22
Winterrogge	3200	0,26	840	210	0,07	130	0,04	22
Rode klaver	4100	0,27	1100	280	0,07	175	0,04	16
Witte klaver	3100	0,27	850	220	0,07	135	0,04	14
Perzische klaver	3400	0,24	800	190	0,06	120	0,03	17
Wikken	2800	0,23	650	155	0,06	95	0,03	12
Facelia	2750	0,24	650	155	0,06	95	0,03	20
Afrikaantjes	3850	0,22	850	195	0,05	120	0,03	20
Spurrie	2900	0,22	625	145	0,05	90	0,03	

[1] Gezaaid vóór 1 september

[2] H.C. = humificatiecoëfficiënt: de fractie die één jaar na toediening van het vers organisch materiaal nog over is in de bodem.

[3] De hoeveelheid die 5 en 10 jaar na toediening van het vers organische materiaal nog over is in kg per ha en als fractie van de beginhoeveelheid.

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