

Assessment of dynamic biotic and abiotic
processes at the soil surface affected by
different management systems

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In dedication to my grandmother

Gewidmet meiner Großmutter

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List of Abbreviations

ANOVA	analysis of variance
Ap horizon	plow layer of agricultural soils
B	1500 (calculation factor for total rainfall in 6 minutes on one m ²)
bs	below the soil surface
CF	Conventional Farming
CFE	chloroform fumigation-extraction method
CHCl ₃	chloroform
CH ₄ N ₂ O	urea fertilizer
cm	centimeter
Cmic	microbial biomass
Corg	total organic carbon
Cmic/Corg ratio	ratio of microbial biomass to total organic carbon
C/N ratio	ratio of total carbon to total nitrogen
DIN	German Institute of Standardization
D.O.C.	Dissolved Organic Carbon
e.g.	for example
f	factor of 4.16 (calculation factor from the measured 40 x 50 cm rectangle to m ²)
FAO	Food and Agricultural Organization
Fig	figure
g	gram
GIS	Geographical Information System
Glu	β-glucosidase
H ₀	null hypothesis
ISO	International Organization for Standardization
K	proportion factor of 2.64 (factor according to Vance et al., 1987)
K ₂ SO ₄	potassium sulfate
M	mol
max	maximum
m ³	cubicmeter
mg/g	milligram per gram
ml	milliliter
mm	millimeter
mm ²	square millimeter
mm/h	precipitation in millimeters per hour
MUB	modified universal buffer

MS	management system
N	total nitrogen
NP/g*h	units of micrograms of p-nitrophenol (PN) released per gram soil (moisture free basis) per hour
n.s.	not significant
OOF	Old Organic Farming
pF-value	soil moisture tension as common logarithm of suction power
Pho	acid-phosphatase
pH-value	reverse logarithmic representation of relative hydrogen proton (H ⁺) concentration
PN	p-nitrophenol
P ₂ O ₅	phosphate
Precip	precipitation
Precipitation cum	cumulative precipitation
R	Pearson's correlation coefficient
R ²	coefficient of determination
Temp	temperature
YOF	Young Organic Farming
µg	microgram
°C	temperature in °C
%	percentage
&	and
2004/2005	total experimental period 2004 and 2005
*	significant (5 %)
**	significant (1 %)
***	significant (0.1 %)

1 Introduction

More than 47 % of the agricultural areas of the European Union are characterized as high or very high risk for soil surface sealing. Furthermore approximately 59 % of the soils are prone for erodibility. Therefore the decrease of soil erosion must be a priority of the environmental and sustainable agricultural policy (Le Bissonnais et al., 2005).

In farmed areas the soil surface presents in general a vital interface that receives physical (e.g. tillage, raindrop impact) and chemical (e.g. herbicide, pesticide) impacts (Franzluebbers, 2002a). Furthermore the pore size distribution in the upper 15 cm of the soil surface is affected by tillage systems (Bescansa et al., 2006). According to the management system the biotic and abiotic conditions on the soil surface can change (Dolan et al., 2006) and it is important to understand the microbial processes occurring under different management systems (Melero et al., 2006). Much emphasis has been placed on the soil surface, because in this layer processes such as infiltration, erosion, and gas exchange take place (Green et al., 2006).

The soil structure and therefore aggregation is a key factor to soil organisms, crop production (Langmaack, 1999) as well as water infiltration and thus preventing soil erosion (Franzluebbers, 2002b, Le Bissonnais, 1996; Pinheiro et al., 2004; Youngs and Leeds-Harrison, 1990). The aggregate breakdown in general causes soil surface sealing and after drying out, surface seals will form crusts (Agassi et al., 1981; Bohl and Roth, 1993; Slattery and Bryan, 1994). Therefore the soil surface structure is one of the major factors controlling runoff and subsequently water erosion for cultivated soils and it is furthermore a very important threat to sustainable agriculture (Farres, 1987; Le Bissonnais et al., 2005; Lecomte et al., 2001). However the description of soil structure is still a challenge for soil scientists (Clivati-McIntyre and McCoy, 2006) because of structural complexity as well as the lack of standard methods (Hamblin, 1991).

The state of the soil surface requires careful attention. Soil enzymes have been used as indicators of soil quality and biochemical changes due to agricultural management. Only little information is available of the long-term dynamics of soil enzymes and the relationship to dynamic processes at the soil surface. Kandeler et al. (1996) showed that the study of enzyme diversity and their associated activities provides an effective approach to examining functional diversity in soils. Thus microorganisms are suggested to respond very sensitive to changes in environmental conditions (Dilly and Nannipieri, 2001). Some enzymes are more sensitive to soil management changes and alter more quickly than others, whereas the acid-phosphatase and β -glucosidase are known to be more susceptible to variations of tillage

practices (Green et al., 2006). The enzymes acid-phosphatase and β -glucosidase carry out specific hydrolyses and were selected in these experiments because they catalyze reactions involved in the biogeochemical transformations of P and C and are likely to be an essential component of any assessment of soil microbial and substrate mineralization (Taylor et al., 2002). In addition these enzymes are highly sensitive to abiotic (e.g. climate) and biotic (e.g. aeration) factors which are influenced from management practices (Bandick and Dick, 1999; Dick, 1994; Dick et al., 1996; Green et al., 2006; Schinner and Sonnleitner, 1996a).

In the following chapters the effect of conventional and organic farming management systems on soil quality properties such as enzyme activity of acid-phosphatase and β -glucosidase, microbial carbon and organic content, pH-value, nitrogen content, C_{mic}/C_{org} ratio, C/N ratio and the susceptibility to soil surface sealing are discussed. These biotic and abiotic parameters were chosen, because Knight and Dick (2004) as well as Schinner and Sonnleitner (1996b) mentioned that in addition to the enzyme activity the assessment of other biotic and abiotic factors is essential to fully evaluate the soil capacity. Furthermore Green et al. (2006) state that these factors are sensitive to soil management in the surface layer as well as fast and easy determinable.

The objective of this study is to improve the understanding of soil microbiological and soil physical dynamic changes in different management systems. Two organic farming sites with different dates of conversion from conventionally to organic farming were chosen as well as one conventional farming site.

To evaluate the potential for organic farming, the study was undertaken in field and laboratory experiments on comparable soils with different land use histories. This dissertation is based on 4 hypotheses:

1. The management system has an influence on the dynamic biotic processes at the soil surface
2. The management system has an influence on the dynamic abiotic processes at the soil surface
3. The management system have a considerable impact on soil aggregation and runoff patterns
4. The soil enzyme activities of acid-phosphatase and β -glucosidase are useful indicators for changes in the management system

2 State of the Art

2.1 Soil enzymes

In general the soil enzymes are the most important mediators of biological processes in soil (Marx et al., 2001). They are primarily of microbial source, but could also originate from plants and animals (Tabatabai, 1994). Enzymes are proteins which catalyze biochemical reactions and play an important part in nutrient cycling and in the initial phases of decomposition of organic matter in soils (Acosta-Martinez et al., 2003a, b; Beck and Beck, 2000; Kiss et al., 1975; Marx et al., 2001). They convert nutrients from unavailable forms to easily assimilate nutrients for plants and microorganisms (Pinton et al., 2001; Marx et al., 2005). Beck and Beck (2000) as well as Dick and Tabatabai (1978) indicate that the activation energies of enzyme catalyzed reactions in soil is lower than of non enzyme catalyzed reactions. The reaction rate of enzyme catalyzed reactions related to substrate concentration can be described by the Michaelis-Menten equation. According to Briggs and Haldane (1925), Nelson and Cox (2000) and Michaelis and Menten (1913) the Michalis-Menten kinetic model is only valid when the concentration of enzyme is much lower than the concentration of substrate.

Skujins (1976) built up a schematic diagram that shows the components of the enzyme activity in soils (Fig.1).

Origin		Enzymatic activity in soil						Endocellular enzymes of proliferating microorganisms, plant roots, soil fauna	
		Abiotic enzymes							
		Accumulated enzymes				Continuously released extracellular enzymes			
		Bound to microbial cellular components			Not associated with cellular components		From microorganisms		From plant roots
		In non proliferating cells	In intact dead cells	In cellular fragments	from soil fauna and microorganisms				
Endocellular enzymes from disrupted cells	Extra-cellular enzymes				In liquid phase				
Location in soil	Bound to soil components					In organisms			

* according to Skujins, 1976

Fig. 1 Scheme of the composition of soil enzyme activities*

According to Figure 1 the enzymatic activity in soil is a result of the activity of accumulated and continuously released extracellular enzymes produced by microorganisms and plant roots, as well as from endocellular enzymes derived from microorganisms, plant roots and soil fauna (Burns, 1982; Kiss et al., 1975; Criquet et al., 2004). According to Schinner and Sonnleitner (1996a) as well as Tabatabai (1994) the microorganisms are supplying most of the soil enzymes, because they have a large biomass and a high metabolic activity which allows them to produce and release more extracellular enzymes than plants or animals.

In general soil enzymes are divided into:

- Intracellular (biotic) enzymes; which occur in living cells, are associated with active microorganisms or occur in dead cells (Beck and Beck, 2000; Dick, 1997; Schinner and Sonnleitner, 1996b)
- Extracellular (abiotic) enzymes; they are either free or absorbed by clay minerals or incorporated into humic colloids (Alef, 1991; Beck and Beck, 2000; Nannipieri et al., 2002; Skujins, 1976; Tabatabai, 1994).

The extracellular enzymes are the main resources by which soil microbes degrade complex organic compounds into smaller molecules which can be assimilated by plants and microorganisms (Allison and Vitousek, 2005).

The activity rates of all soil enzymes are depending on temperature, pH and the presence or absence of inhibitors as well as activators. Each enzyme has a pH-value and temperature scale, at which the activity rate is optimal and at each side of this optimum the rate is lower. They are denatured by extreme pH in soils and enhanced temperatures (Tabatabai, 1994) between 60 °C and 70 °C (Frankenberger and Tabatabai, 1980, 1981; Tabatabai and Dick, 1979).

According to Pinton et al. (2001) the enzyme activity in the rhizosphere is in general higher than in bulk soil. This is a consequence of organic exudates, passively or actively released by plant roots, which stimulate microbial activity and thus enzyme production. Root exudation is according to Renella (2006) the major factor for microbial activity and community structure in the rhizosphere. Furthermore Burns (1982) and McLaren (1975) show that the total enzymatic activity is influenced by organic and mineral parts in the soil as well as in the rhizosphere, because free enzymes can be adsorbed on organic and mineral constituents. Depending on their location in soil, the enzymes are more or less sensitive to environmental changes (Nannipieri et al., 2002). In general the soil enzyme activities vary with the cropping and management system (Bandick and Dick, 1999; Ekenler and Tabatabai, 2003b; c; Knight and Dick, 2004), can indicate soil property changes early (Powlson et al., 1987; Acosta-

Martinez and Tabatabai, 2000a, b), and are strongly linked to microbial activities (Deng and Tabatabai, 1996a, b; Klose et al., 1999; Klose and Tabatabai, 2000). On the basis of these findings, enzymes could be used as an indicator for ecosystem health, soil biological quality and soil quality in general (e.g. Badiane et al., 2001; Bandick and Dick, 1999; Deng et al., 2000; Dick, 1997; Dick and Tabatabai, 1992; Dilly, 1994; Ekenler and Tabatabai, 2004; Stott and Green, 2002; Verchot and Borelli, 2005). It should be recognized that the use of one simple index for soil quality is not enough (Sojka and Upchurch, 1999), because enzyme activity is also linked to the distribution of other biological, chemical and physical properties such as soil moisture and organic matter content (Bergstrom et al., 1998; Knight and Dick, 2004). Knight and Dick (2004) suggested that further research is necessary to understand which mechanisms are responsible for the enzymes to expand the enzyme analyses as a tool to guide sustainable soil management.

2.1.1 Phosphatases

Phosphorus (P) is a key nutrient for plant growth and can be utilized from plants only in inorganic form (Tate, 1984), therefore the release of bioavailable P (inorganic form) from the phosphatases is a major source in various ecosystems (Drouillon and Merckx, 2005; Tabatabai, 1994). Among the hydrolases, phosphatases are widely distributed in soil (Dodor and Tabatabai, 2003) and play a key role in mineralization of organic to inorganic phosphorus (Beck et al., 1989), P cycling and plant nutrition (Tabatabai, 1994; Klose et al., 2003; Tate, 1984). The enzymes are generally found in plant roots, microorganisms and in extracellular forms in soil (Criquet et al., 2004). According to Tabatabai (1994) phosphatases are mostly a source of microorganisms and could be used as an indicator of microbial activity (Frankenberger and Dick, 1983). In general the phosphatases describe enzymes that catalyze the hydrolysis of organic phosphomonoester to inorganic phosphorous (H_2PO_4^- and HPO_4^{2-}), making it available for plant uptake (Alef and Nannipieri, 1995; Amador et al., 1997; Ekenler and Tabatabai, 2003b; Kramer and Green, 2000; Schmidt and Laskowski, 1961; Tabatabai, 1994).

Researchers who worked with phosphatases test also their correlations with other factors to find possible interactions. Therefore Clarholm (1993) suggests that phosphorus (P) fertilization inhibits phosphatase activity and that available nutrients often correlate negatively with the activities of nutrient-releasing enzymes (Chróst, 1991; Sinsabaugh and Moorhead, 1994). Schinner et al. (1996) stated that while some researchers found negative correlations between phosphatase activity and organic P other authors found positive relations between these two variables. However Criquet et al. (2004) found no significant correlations between the activity of acid-phosphatase and the water-extractable P during one year of collection time.

The missing correlation between the enzyme activity and inorganic P may be related to the reason that P is often not a limiting factor. Some other substrates (C, N) or interferences from humic substances could rather limit the phosphatase production (Olander and Vitousek, 2000).

Allison and Vitousek (2005) suggest, that only one substrate could never increase the microbial biomass and enzyme activity significantly. However Harder and Dijkhuizen (1983) find if available nutrients are limited, microbes can generate enzymes to activate resources from complex sources.

The Nomenclature Committee of the International Union of Biochemistry and Molecular Biology (NC-IUBMB, 2006) lists all enzymes according to the common names along with their EC numbers. According to the classification of the NC-IUBMB, Schinner and Sonnleitner (1996b), and Tabatabai (1994) classify the soil phosphatases into five major groups:

- phosphoric monoester hydrolases (EC 3.1.3),
- phosphoric diester hydrolases (EC 3.1.4)
- triphosphoric monoester hydrolases (EC 3.1.5)
- enzymes acting on phosphoryl containing anhydrides (EC 3.6.1)
- enzymes acting on P-N bonds (EC 3.9)

The phosphoric monoester hydrolases (EC 3.1.3) are classified as neutral- and alkaline-phosphatase (pH 7-11) (orthophosphoric monoester phosphohydrolase, pH 11, EC 3.1.3.1), and acid-phosphatase (pH <7) (orthophosphoric monoester phosphohydrolase, pH 6.5, EC 3.1.3.2) according to their pH optimum (Acosta-Martinez et al., 2003a; Beck and Beck, 2000; George et al., 2002; Schinner and Sonnleitner, 1996b; Verchot and Borelli, 2005). Due to the pH optimum the acid-phosphatase has been studied extensively (Dodor and Tabatabai, 2003).

Acid-phosphatase (EC 3.1.3.2)

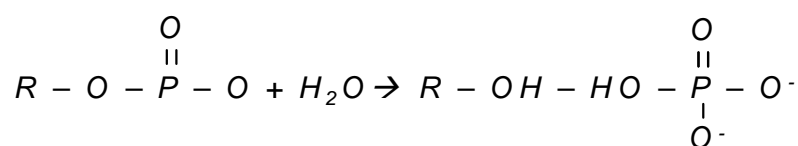
The phosphatases can originate from different sources. The main sources are microorganisms such as bacteria, fungi or protozoa, plant roots and animals. The plant roots may constitute the main source of acid-phosphatase (Juma and Tabatabai, 1988; Criquet et al., 2004; Tarafdar and Marschner, 1994).

The acid-phosphatase (EC 3.1.3.2) is a phosphoric monoester hydrolase (EC 3.1.3) and acts on ester bonds (Deng and Tabatabai, 1997). Other name(s) of the acid-phosphatase are (NC-IUBMB, 2006):

- acid-phosphomonoesterase
- phosphomonoesterase
- glycerophosphatase
- acid-monophosphatase
- acid-phosphohydrolase
- acid-phosphomonoester hydrolase
- uteroferrin
- acid nucleoside diphosphate phosphatase
- orthophosphoric-monoester phosphohydrolase

The reaction catalyzed by acid-phosphatase is in general (NC-IUBMB, 2006; Tabatabai, 1994; Schinner and Sonnleitner, 1996a):

Phosphate monoester (β-Nitrophenylphosphat) + H₂O → ROH (p-Nitrophenol) + Phosphate



Studies by Eivazi and Tabatabai (1977) and Dick et al. (2000) on the distribution of phosphomonoesterases in soils show that acid-phosphatase (pH <7) activity was predominant in acid soils (George et al., 2002), suggesting that the rates of synthesis and release of these enzymes by soil microorganisms are related to soil pH and moisture distribution (Turner et al., 2002). Studies of Deng and Tabatabai (1997c) show that the soil pH value is in a narrow acid range the acid-phosphatase activity is not significantly correlated with soil pH (R=0.20). In general, the distribution of acid-phosphatase is depending on the soil depth. Stott and Green (2002) found in accordance a higher activity in soil samples from the top 5 cm of soil surface than in 5 to 20 cm and 20 to 30 cm, respectively.

The acid-phosphatase activity is frequently used to describe changes in soil quality due to the management system sources. According to Ekenler and Tabatabai (2003b) the acid-phosphatase is a sensitive indicator to show general changes in soil health and quality as a result of agricultural practices and can be used as an index of quantity and quality changes of organic matter in soils (Chen et al., 2000; Jordan et al., 1995; Bergstrom et al., 2000).

According to Boerner et al. (2005) the acid-phosphatase activity is an indicator for the overall microbial activity. Deng and Tabatabai (1997), Dick (1984) and Dodor and Tabatabai (2003) report a significant relationship between the activities of acid-phosphatase and organic C in soils under different tillage and rotation systems. Furthermore Yu et al. (2006) point out, that the acid-phosphatase is significantly correlated to total organic C ($P < 0.001$) and total P ($P < 0.01$). Deng and Tabatabai (1997) suggested that organic C plays an important role in maintaining and protecting soil enzymes in their active forms. Stott and Green (2002) showed a potential of acid-phosphatase as an indicator of aggregate stability.

2.1.2 Glycosidases

Glycosidases are enzymes which are involved in cycling of soil organic matter (OM) (Dodor and Tabatabai, 2005). They are widely distributed in nature and detected in microorganisms, animals, plants (Wallenfels and Weil, 1972) and soils (Skujins, 1976). The glucosidases in soils are classified according to the commission on enzymes of the International Union of Biochemistry. The following glucosidases are predominant in soils (Dodor and Tabatabai, 2005):

- α -glucosidase (EC 3.2.1.20), which catalyzes the hydrolysis of α -D-glucopyranoside
- β -glucosidase (EC 3.2.1.21), which catalyzes the hydrolysis of β -D-glucopyranoside

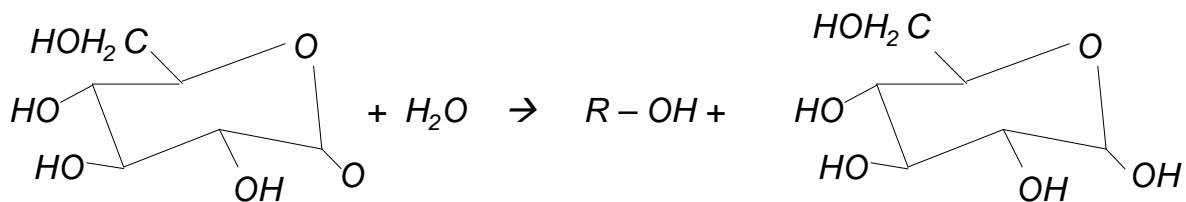
The α -glucosidase and the β -glucosidase are involved in the hydrolysis of maltose and cellobiose. They produce sugars, which act as an important energy source for microorganisms in soils (Acosta Martinez et al., 1999; Bandick and Dick, 1999; Knight and Dick, 2004; Tabatabai, 1994), and thus play an important role in the initial phases of decomposition of organic C compounds (Klose et al., 2003).

The α -galactosidase (EC 3.2.1.22) and β -galactosidase (EC 3.2.1.23) are other soil glucosidases, which catalyze the hydrolysis of melibiose and lactose, but compared to the glucosidases they are not presented in significant levels (Dodor and Tabatabai, 2005).

In general the activity of glycosidases in soil is affected by management practices (Bandick and Dick, 1999; Deng and Tabatabai, 1996b), because varying cropping systems alter the soil environment in different extensions. Due to these findings, the activity of glucosidases can be used as a sensitive indicator of changes in the soil environment (Dodor and Tabatabai, 2005).

β -D-Glucosidase (EC 3.2.1.21)

The β -D-glucosidase (other names according the NC-IUBMB (2006) are: gentiobiase; cellobiase; emulsin; elaterase; aryl- β -glucosidase; β -glucoside glucohydrolase; arbutinase; amygdalinase; p-nitrophenyl β -glucosidase; primeverosidase; amygdalase; limarase; salicilinase; β -1.6-glucosidase) is the most predominant enzyme among the glucosidases in soils and plays a major and important part in C cycling (Eivazi and Tabatabai, 1990; Klose et al., 2003). The β -glucosidase is involved in the final step of cellulose degradation that provides simple sugars (β -D-glucose) for microorganisms in soils (Bandick and Dick, 1999; NC-IUBMB, 2006) which are known as important energy sources for the growth of soil microorganisms (Deng and Tabatabai, 1996b). The reaction involved is according to Schinner and Sonnleitner (1996a) and Tabatabai (1994):



Acosta-Martinez et al. (1999), Bandick and Dick (1999), Eivazi and Tabatabai (1990), Knight and Dick (2004) as well as Ndiaye et al. (2000) show that the β -glucosidase activity acts sensitive to residue and soil management and is a good soil quality indicator, as well as it is relatively stable with seasons (Ndiaye et al., 2000). Dodor and Tabatabai (2003), Knight and Dick (2004), Moore et al. (2000) and other researchers detected that the β -glucosidase activity is significantly correlated to the organic C content of soils. Furthermore Taylor et al. (2002) pointed out that the activity of β -glucosidase is a function of soil depth. They find higher activity values at the soil surface (30 cm) compared to the deeper soil. Previous work of Stott and Green (2002) shows that the activity in soil samples of 0 - 5 cm is higher than in soil samples of 5 - 20 cm and 20 - 30 cm depth.

With regard to the enzymes involved in the carbon cycle, β -glucosidase has been widely used in the evaluation of soil quality changes due to different management procedures (Gil-Sotres et al., 2005) and can be used to detect changes in soil management within a time span 1 to 3 years (Bandick and Dick, 1999).

2.2 Management systems

Since centuries tillage has been generally used to produce appropriate seedbeds to optimize plant growth and productivity (Niewczas and Witkowska-Walczak, 2003; Zhang et al., 2006). Soil tillage is a basic and important component of agricultural production technology (Lal, 1985) and can be used as a tool to improve some soil related properties (Lal, 1991b). However, tillage practices influence the upper segment of the soil profile and thereby the allocation of residues (Allmaras et al., 1996), soil compaction, infiltration rate, soil surface crusting, erosion, soil moisture and temperature regimes as well as pest management (Lal, 1991b). According to Vanden-Bygaart et al. (1999) soil management practices can affect processes occurring at multiple scales. The appropriate tillage system for a particular soil has often positive effects and can decrease e.g. soil erosion or increase the available soil water content for crop growth (Wendt and Burwell, 1985).

The soil is an essential natural resource that provides several important ecosystem functions, e. g. (Karlen et al., 1997; Larson and Pierce, 1991)

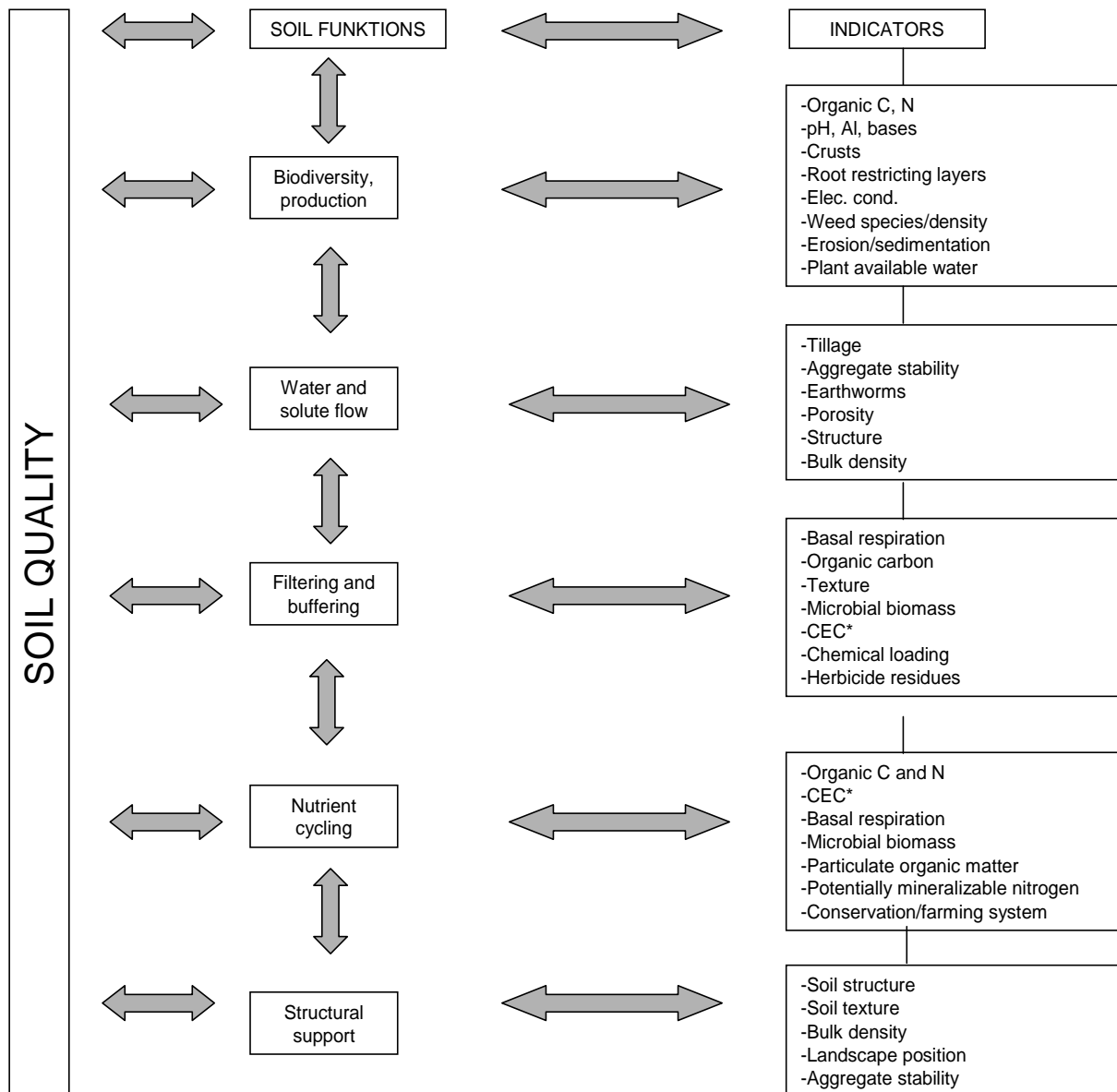
- Sustaining biological diversity and activity
- Regulating water flow
- Storing and cycling of nutrients

Major environmental problems are soil degradation processes (Pagliai et al., 2004), especially soil surface sealing or crusting, which are well known pedological problems in cultivated soils in several regions of the world (Slattery and Bryan, 1994) and result in agricultural (e.g. soil loss, limited water storage) and environmental (e.g. flooding) consequences (Bresson et al., 2001). Soil surface crusting is generally seen as a considerable causal factor of soil erosion on agricultural land (Kwaad and Mùcher, 1994). Le Bissonnais et al. (2005) stated that surface runoff is generated if the soil infiltration capacity is lower than the precipitation rate and results in general in soil erosion. These processes are characterized of excess rainfall water which transports soil and soil related particles on the surface down slope. According to Auerswald and Kutilek (1998) soil erosion is presumably the largest threat to the soil resource. Le Bissonnais et al. (2005) show that more than 47 % of European soils can be classified as having high or very high crusting risk and more than 59 % as having high or very high erosion risk. One of the main aims of agricultural land management is the reduction of environmental impacts due to cultivation practices and control soil structure degradation. Therefore soil degradation processes must be reduced and put under control (Pagliai et al., 2004; Zhang et al., 2006). In recent years the interest focused on improving the stability of soil structure, because the soil must retain positive biological, chemical and physical properties when exposed to raindrop impact and

other externally applied stresses (Connolly, 1998). Wander and Bollero (1999) state that soil quality assessment strategies are needed to improve sustainable soils for agriculture use.

2.2.1 Soil quality concept

The soil quality concept is under constant development (Peixoto et al., 2006) and based on the hypothesis that the management system can degrade, stabilize, or improve soil ecosystem functions (Doran and Parkin, 1994; Larson and Pierce, 1991). They propose that indicators for measuring the soil quality should reflect the capacity of soil functions (Fig. 2).



*CEC =Cation exchange capacity, ** modified after Seybold et al. (1998)

Fig. 2 The concept of soil quality**

According to Dexter (2002) soil quality is strictly related to soil structure and much of the environmental damage in intensive arable lands such as compaction, erosion and desertification originate from soil structure degradation. Soil functions strongly depend on the quality of soil structure. Maintaining a good soil surface structure enhances water infiltration and reduces runoff of well drained soils (Bradford and Huang, 1994, Doran, 2002). According to Franzluebbbers (2002b) adequate soil management techniques can be expected to restore ecosystem functions of previously degraded soils. The concept of soil quality has recognized that soil organic matter is an important feature to control many of the soil key functions (Arshad et al., 1999; Campbell et al., 1991; Doran and Parkin, 1994) such as soil aggregation and water infiltration and control erosion (Franzluebbbers, 2002b). Angers et al. (1993) and Stott et al. (1999) propose that biological properties are important indicators of soil quality and those microbial indicators, such as microbial biomass are more dynamic indicators than those based on physical and chemical properties (Karlen et al., 1994; Peixoto et al., 2006). In recent years, there has been increasing attention paid to conservation tillage, which can improve soil quality (Gajri et al., 2002).

2.2.2 Tillage management

Increasing interest in long-term productivity of agro-ecosystems has emphasized the need to develop management strategies that maintain and protect soil resources. Tillage and soil surface management play an important role in sustainable management of soil and water resources (Lal, 1991a). The issue is directly related to maintaining the quantity of soil organic matter (Gregorich et al., 1997) as well as a critical component of soil productivity (Chander et al., 1997). The different tillage and related crop residue management practices have a major influence of organic matter (Duiker and Lal, 1999; Havlin et al., 1990; Robinson et al., 1994; Wander et al., 1994; Wander and Traina, 1996). In recent times attention was focused on the impacts that agricultural soil management practices had on biological and biochemical properties of soils (e.g. Gregorich et al., 1994; Franzluebbbers et al., 1995b). It has led farmers to consider the possibility of adopting lower impact cultivation practices as an alternative to conventional farming (Cannell and Hawes, 1994), because one of the main consequence of long-term intensive cultivation is the degradation of soil structure (Pagliai et al., 2004). The final choice which tillage management should be used depends on several factors according to Lal (1991b) and is shown in Fig. 3.

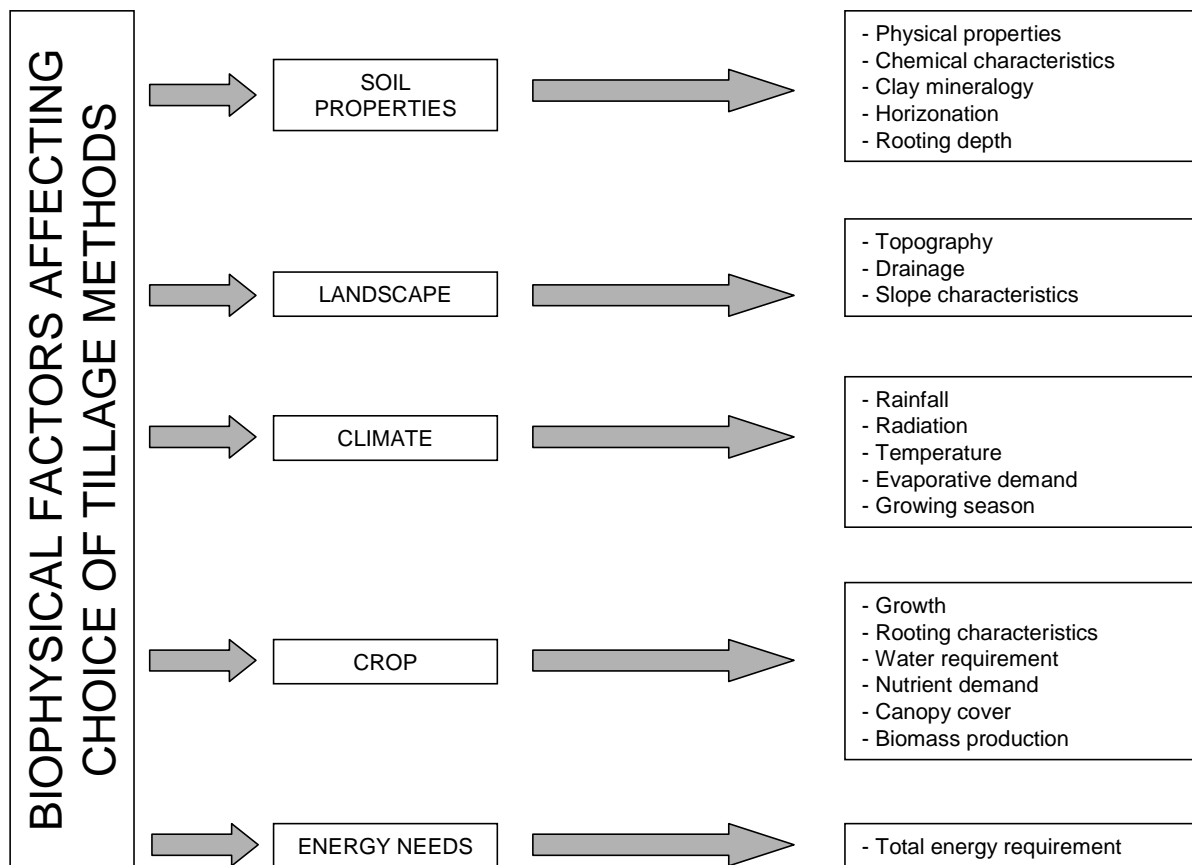


Fig. 3 Biophysical factors which affect the choice of the tillage system (Lal, 1991b)

In general mechanical tillage practices (e.g. seedbed preparation, controlling weeds) alter the balance of air and water in soil and therefore affect plant growth (Arshad et al., 1999). However plowing is efficient for control of perennial weeds and may be necessary where these weeds are difficult to control by other means (Hakansson et al., 1998).

2.2.2.1 Conventional tillage

Moldboard plowing has been the traditional method of primary tillage for annual crops (Moreno et al., 2006). The main objectives for this tillage management are to control weeds, reverse soil compaction (Hakansson et al., 1998; Schutter and Dick, 2002) and to incorporate and distribute crop residues in the arable soil layer (Bescansa et al., 2006; Hakansson et al., 1998). Numerous researchers (e.g. Dalal and Mayer, 1977; Balota et al., 2003; Elliott, 1986; Haines and Uren, 1990; Kay, 1990; Lal, 1991b; Tisdall and Oades, 1982) have demonstrated that conventional farming systems of excessive tillage enhance risks of soil erosion, increase rates of mineralization of soil organic matter and degrade soil structure, and as a result, accelerate soil erosion. On sandy soils plowing is favorable, because the plowing resistance is low and plowing as deep as 30 cm may reduce the need for other measures to control perennial weeds (Hakansson et al., 1998).

2.2.2.2 Conservation tillage

Conservation tillage management is characterized by a number of tillage practices which have the potential to decrease soil degradation processes, relative to conventional tillage management (Mannering and Fenster, 1983). In general conservation tillage has been defined as any tillage system that maintains at least 30 % of the soil surface covered by residue (Lal, 1997). The soil conservation management differs from the conventional approach by reduced numbers of tillage operations and the maintaining residues at the soil surface (Dolan et al., 2006; Moreno et al., 2006). Organic farming is according to Acosta-Martinez et al. (2003a, b) a more sustainable farming system than conventional farming and a change from inorganic fertilizer to organic forms causes changes in the soil fertility and can affect plant growth. Mäder et al. (2002) described that in some European countries up to 8 % of the agricultural area is managed organically according to European Union Regulation (EEC) No. 2092/91. In general the seeds are inserted into the soil through plant residues with no primary or secondary tillage (Gupta and Germida, 1988). These management practices have the potential to maintain and improve soil quality (Balota et al., 2003; Zhang et al., 2006). Many studies have shown that the effect of reduced and no-tillage management systems in well established conservation tillage systems results in better soil structural stability (Gupta and Germida, 1988; Wright and Hons, 2005) improves water infiltration which causes a reduction of soil erosion and enhances water storage (Arshad et al., 1999; Bradford and Huang; 1994; Moreno et al., 2006; Shipitalo et al., 2000; Smith et al., 2006; Wendt and Burwell, 1985). Conservation tillage management leads to increased soil compaction (Vanden-Bygaart et al., 1999) as a result that water infiltration may be similar or lower than under conventional tillage systems due to initial compaction and lack of sufficient biological activity in the first few years after conversion (Lindstrom and Onstad, 1984; Unger, 1992).

Beare et al. (1994a ; b), Dick (1983), Franzluebbers et al. (1995a), Halvorson et al. (2002) and Lal et al. (1994) report an increase in soil organic C content in surface soils near the rooting zone because of high-crop residue input and lack of soil disturbance. Conservation tillage can increase soil aggregation (Paustian et al., 1997; Hendrix et al., 1998) as a result of increased SOM content (Six et al., 2000). Reduced tillage usually results in an increase in soil biological properties (Doran, 1980; Salinas-Garcia et al., 1997; Vanden-Bygaart et al., 1999) and in earthworm numbers (Ehlers, 1975; Kladivko et al., 1997).

3 Material and methods

3.1 Experimental location

The investigations took place in the federal state of Schleswig-Holstein (Germany) about 25 km north of Kiel near the Baltic Sea (25°29' S; 10°04' W, 25 m above sea level; Fig. 4). The climate is influenced by the North Sea and the Baltic Sea (Dilly and Nannipieri, 2001). The annual precipitation is approximately 774 mm and the average annual air temperature is 8.7 °C at the experimental station "Lindhof" (Neumann et al., 2004). The Schleswig-Holstein landscape at the Baltic Sea, called "Östliches Hügelland" was modeled by the power of glaciers during the Weichsel ice age (115.000 – 14.500 years ago) and melt waters producing round-topped hills in northern Germany (Liedtke and Marcinek, 2002; Meynen and Schmithüsen, 1962). The soils in this region show young moraine indices until today and have been cultivated by farmers for centuries. The sites are framed by hedgerows, with streams and small patches of woodland (Richter, 2005; Scharnweber, 2006).

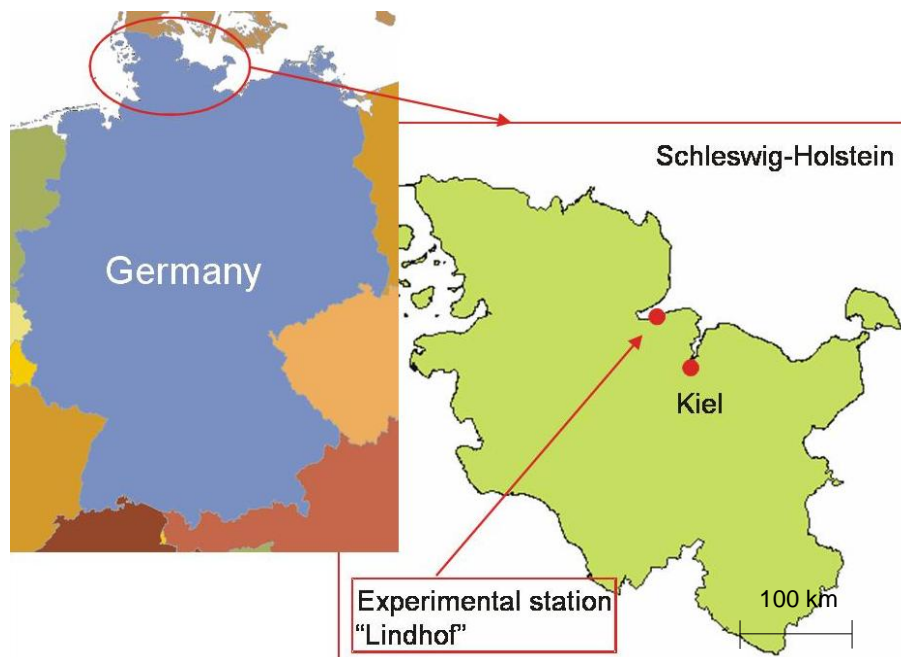


Fig. 4 Location of the experimental station "Lindhof"

For the investigation two organic farming sites with different conversion dates from conventional to organic management and one conventional management site (located between 3 km distance) were chosen (Fig. 5):

1. Old Organic Farming (OOF) site:
 ➡ Managed according the standards of the "Naturland" Association since 1997
2. Young Organic Farming (YOF) site:
 ➡ Managed according the standards of the "Naturland" Association since 2004
3. Conventional Farming (CF) site:
 ➡ Intensive production system since 40 years

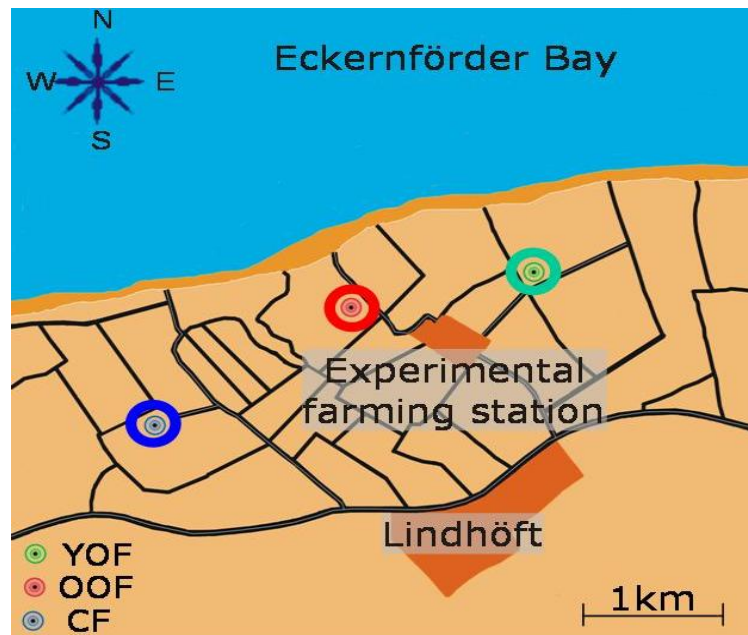


Fig. 5 Location of the Old Organic Farming (OOF), Young Organic Farming (YOF) and Conventional Farming (CF) sites

3.2 Management systems

3.2.1 Organic Farming

The implementation of the definition of organic farming is based on the 'Basic Standards for Organic Agriculture and Processing' of the International Federation of Organic Agriculture Movements (IFOAM). These basic standards provide a framework for certification programs world wide to develop their own national or regional standards. The soil cultivation at the Old Organic Farming (OOF) and Young Organic Farming (YOF) site was characterized by disk harrow cultivation in fall, sowing an intercrop between the vegetation periods and plowing in spring (Table 1). The weed control at the organic farming sites was only mechanical. Synthetic fertilizers as well as pesticides are not allowed at this management system. An excerpt of the "Naturland" (<http://www.naturland.de>) standard for plant production is shown in detail in Annex 1.

3.2.2 Conventional Farming

The Conventional Farming (CF) is an intensive farming system which involves plowing, followed by secondary tillage operations to produce a fine seedbed. Additionally most of the plant residue from the previous crop is removed. In the CF farming system pesticides and fertilizers can be applied according to the rules of Good Agricultural Practice as defined by the framework of German legislation (§ 17 Abs. 2 BBodSchG, 1998; BGBl. I. S. 118ff. 1996; § 2a Abs. 1 and 2 PflSchG, 1998; § 3d Abs. 1 BNatSchG, 1998). Regarding to the management system and crop rotation the cultivation practices differed between the Old Organic Farming, Young Organic Farming and Conventional Farming sites (Table 1).

3.3 Field experiment

3.3.1 Cultivation practices

In Table 1 the cultivation practices at the Organic and Conventional Farming sites were shown in detail for the year 2004 and 2005, as well as the crop rotation since 2001.

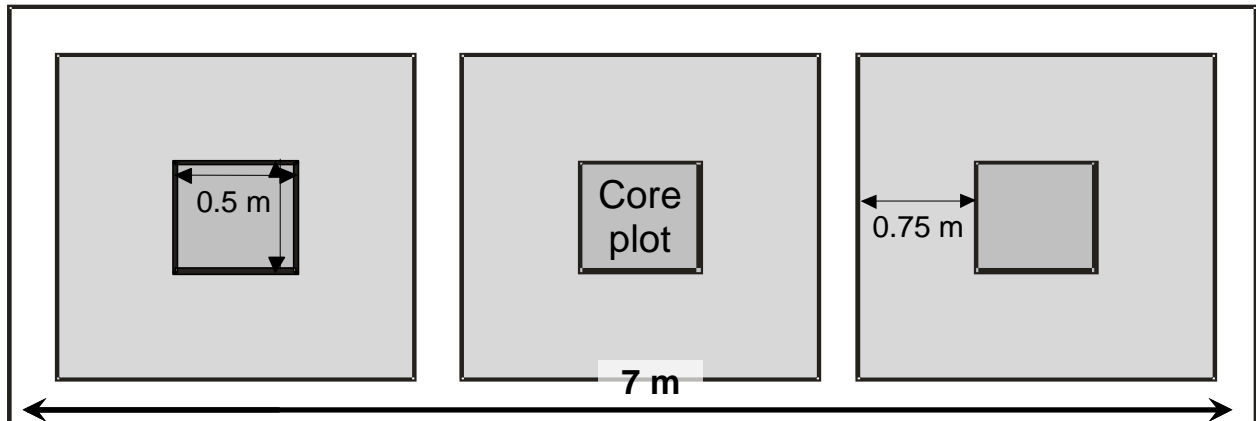
	OOF*	YOF*	CF*
Intercrop 05/06 Main crop 2005	grass as catch crop pea	spelt pea	--- winter wheat
Intercrop 04/05 Main crop 2004	green rye oat	green rye oat	--- corn (zea mays)
Intercrop 03/04 Main crop 2003	clover clover	clover clover	--- winter wheat
Intercrop 02/03 Main crop 2002	clover winter wheat & clover	clover pea/summer barley silage	--- winter rape (canola)
Intercrop 01/02 Main crop 2001	---- potatoes	--- winter wheat	--- winter wheat
cultivation practices: 2005	07. Apr.: harrow disc 12. Apr.: plowing & sowing pea 13. Apr.: rolling 22. Aug.: harvest 25. Aug.: liming 02. Sep.: harrow disk 06. Sep.: ripper 07. Sep.: sowing grass as catch crop	07. Apr.: plowing / harrow & sowing pea 18. Aug.: harvest 25. Aug.: liming 01. Sep.: harrow disc 15. Sep.: ripper 07. Oct.: plowing & sowing spelt	07. Feb.: 15m ³ liquid manure (cattle) 20. Mar.: urea (CH ₄ N ₂ O) 24. Mar.: sulphur and potassium fertilizer 01. Apr.: potassic fertilizer 26. Apr.: urea (CH ₄ N ₂ O) 01. Jun.: urea (CH ₄ N ₂ O) 03. Jun.: herbicides (input / U46M / impulse) 18. Aug.: harvest 21. Aug.: liming 29. Aug.: liquid manure (cattle) 30. Aug.: plowing & sowing winter rape 31. Aug.: pesticide
2004	04. Mar.: liming 18. Mar.: harrow disk 24. Mar.: phosphate fertilizer (P ₂ O ₅) 31. Mar.: plowing 01. Apr.: sowing oat 28. Apr.: rolling 17. Aug.: harvest 23. Aug.: plowing 02. Sep.: sowing green rye	05. Apr.: harrow disk 15. Apr.: plowing and sowing oat 28. Apr.: rolling 17. Aug.: harvest 03. Sep.: plowing 08. Sep.: sowing green rye	14. Apr.: liquid manure (cattle) 17. Apr.: plowing 18. Apr.: sowing corn 23. Apr.: urea (CH ₄ N ₂ O) 12. May: herbicide (gardo gold / Callisto) 11. Oct.: harvest 14. Oct.: plowing & sowing winter wheat

*OOF=Old Organic Farming site; YOF=Young Organic Farming site; CF=Conventional Farming site

Table 1 Cultivation practices in 2004 and 2005, as well as crop rotation since 2001 at the OOF, YOF and CF site

3.3.2 Plot setup

At each site three core plots of 0.5 x 0.5 m surrounded by a buffer zone of 0.75 m width were established in the cultivated field site (Fig. 6). The core and the buffer zone were kept free of vegetation during the experimental periods in 2004 and 2005 to allow the maximum development of soil crust. The selected experimental plots received the same cultivation practices as the field crops.



3.4.1 Rainfall tower

The rainfall tower (approx. 12m high) was built in the year 2003 to simulate the natural rainfall under laboratory conditions. The rainfall simulator was placed at 9 meters height in the rainfall tower. The rainfall simulator consisted of plastic (120 cm² base area, 40 cm height) with good dimensional stability (PVC with a material thickness of 1 cm). In the core 10000 cm² of the base plate, 2500 capillaries with an external diameter of 2.5 mm and internal diameter of 0.5 mm are bonded. The capillaries have a length of 2.5 cm and are located to be exposed 0.5 cm inside and 1 cm outside the rainfall simulator. In each capillary, wires of stainless steel with a length of 2.6 cm and an external diameter of 0.3 mm were placed. Thirty centimeter below the rainfall simulator a mesh with an aperture size of 2 mm was suspended (Fig. 7; Table 2).

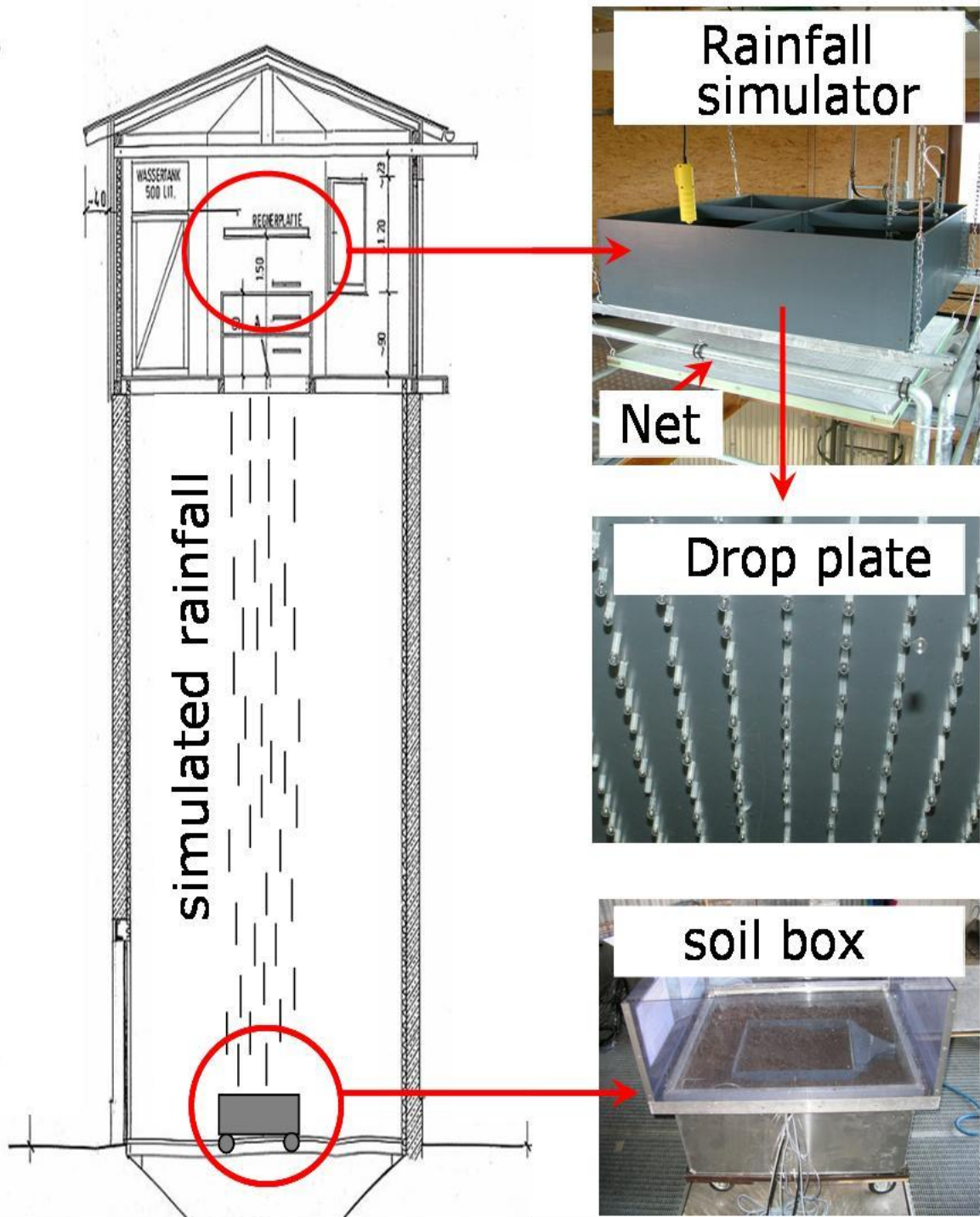


Fig. 7 Rainfall tower, rainfall simulator (drop plate) and net at the sealing part of the rainfall tower as well as soil boxes at the floor

The drops of the rainfall simulator were destructed by the mesh below the drop plate and new drops with drop size diversity between 0.125 mm and 5 mm were formed and fell down to the soil erosion boxes which were placed under the rainfall simulator (Fig. 7). The developed rain drops reached a velocity range of 0.2 m/s to 7 m/s and an average E_{kin} of $30.85 \text{ J m}^{-2} \text{ h}^{-1}$ (15 mm precipitation). The drop size as well as the drop velocity was measured with a Laser Precipitation Monitor (Thies clima, Göttingen, Germany). All rainfall experiments were conducted with collected rain water, which was stored in a rainwater storage tank (2000 liter). The rainfall intensity could vary between 10 and 120 mm per hour according to the water level in the rainfall simulator which was controlled with a float control (Table 2).

Table 2 Technical details of the rainfall tower and rainfall simulator

Technical configuration	Rainfall simulator
Area	10000 cm ²
Capillaries	2500
Drop formation	Mesh (2 mm aperture size) 30 cm below drop plate
Water supply	Float control
Possible intensity range	10 - 120 mm/h
Height of fall	8.50 m
Capillary length	25 mm
Inside diameter	0.5 mm
Space between the capillary	20 mm
Stainless steal wire length	26 mm
Diameter of stainless steal wire	0.3 mm
Drop range	0.125 mm – 5 mm*
Average drop diameter	1.7 mm*
Velocity range	0.2 m/s – 7 m/s*
Average drop velocity	2.028 m/s*
Average E_{kin} for 15 mm precipitation	$30.85 \text{ J m}^{-2} \text{ h}^{-1}$

*measured with a Laser Precipitation Monitor (Thies clima, Göttingen, Germany)

The surrounding floor was built with stainless steel grates to maintain a dry floor during the rainfall experiment. The excess rain water was collected under the floor and pumped into the gully. The soil boxes for runoff and erosion experiments were stored at the dry part of the basement floor and were moved for the precipitation/erosion experiment into the middle of the rainfall tower.

3.4.2 Soil box setup

In the laboratory rainfall experiment the same soils as in the field experiments were used. The soil was collected from the upper 10 cm of the soil surface of each field plot at 14-October-2005, and afterwards filled in boxes of 80 cm to 90 cm in square and 40 cm height. Each field site was represented by two boxes. After 4 weeks of natural subsidence soil aggregates were manually placed at the soil surface to reach a comparable aggregation ratio between the treatments. The aggregates placed at the soil surface were in dimensions between 2 cm² and 16 cm². Prior to each rainfall event a slope of 6 % was adjusted by a hydraulic jack to allow the origin of soil surface runoff. At the surface of each soil box an inner unit (erosion plot) of 40 to 50 cm in rectangle was selected to measure the runoff at the soil surface. 3 cm below the surface of each soil erosion box, temperature sensors as well as probes to measure the matrix potential were placed to quantify the infiltrated rainwater. Furthermore at the base of each box, four suction plates (EcoTech, Bonn, Germany) were installed to control soil moisture in the soil box between the rainfall events (Fig. 8).

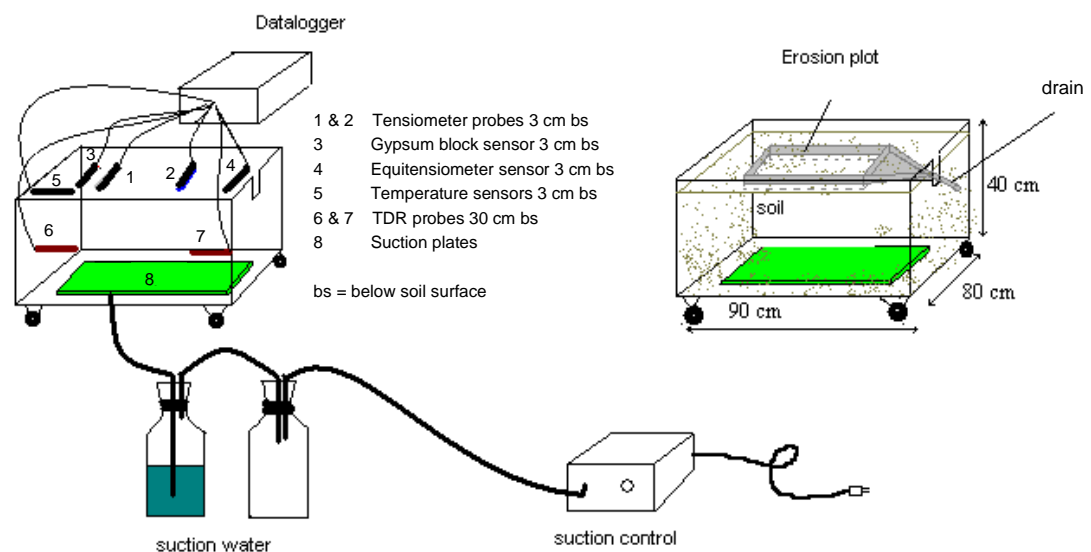


Fig. 8 Soil box setup with erosion plot, suction plates and suction control

3.4.3 Rainfall experimental setup

The rainfall experiment was conducted in 7 day intervals (10 times) with an intensity of 15 mm precipitation per hour for one hour duration. Between the rainfall intervals the soil boxes were stored in the rainfall tower at 14 to 16°C, and the soil surfaces were dried with fans for 6 days to reach the maximum development of soil crusting.

3.5 Soil sampling

Field experiment

The soil samples were taken from the buffer zone (three replications at each site) of the upper 3 cm of the bare soil. In 2004 the sampling was conducted on the basis of the vegetation period at the OOF, YOF and CF site. Samples at the OOF and YOF site were taken biweekly from 30-April to 12-August and from 08-September to 10-November. The sampling scheme included 126 samples at each of the organic farming sites.

At the CF site the soil sampling period ranged from 30-April to 10-November, also using a biweekly interval. The overall number of samples from the CF site in 2004 amounted to 135. In 2005 the soil sampling at all sites started at 03-February under a snow layer of 15 to 20 cm till 23-November-2005. Again, samples were taken biweekly, resulting in 198 per site in 2005.

Rainfall experiment

The soil samples were taken weekly from upper 3 cm from the surrounded buffer zone a few minutes before each rainfall experiments started. The last sample (sample number 11) was taken seven days after the last rainfall event. This sampling scheme included 22 samples each for the OOF, YOF and CF soil.

Soil storage

The soil samples were sieved through a 2 mm mesh and stored field moist at 4 °C until the analyses were conducted. Studies of Ekenler and Tabatabai (2003a) as well Dodor and Tabatabai (2005) indicated that the storage temperature and storage time showed no influence on the enzyme activities. All results which are related to the soil weight were referred to the soil dry weight after 48 hours at 105 °C (moisture free basis).

3.6 Monitoring program – field and rainfall experiment

In Table 3 a general overview of the used methods at the field and rainfall experiment is given.

Indicator	Method	Field experiment	Rainfall experiment
Biotic	Acid-phosphatase	X	X
	β -D-Glucosidase	X	X
	Microbial carbon (C _{mic})	X	X
Abiotic	Soil texture analysis	X	X
	Soil surface roughness	X	X
	Precipitation	X (n. c.*)	X (c.**)
	Soil temperature	X (n. c.*)	X (c.**)
	Organic Carbon (C _{org})	X	X
	C _{mic} /C _{org} ratio	X	X
	Nitrogen (N)	X	X
	C/N ratio	X	X
	pH-value	X	X
	Soil moisture content	X	X
	Matric potential	---	X
	Runoff	---	X

* n. c. = not controlled; ** c. = controlled

Table 3 Overview of the used methods at the field and rainfall experiment

3.6.1 Biotic Indicators

3.6.1.1 Enzyme activity

The enzyme activity at the field and rainfall experiment was determined as described by Tabatabai (1994) in triplicate of each soil sample. This method is based on the colorimetric determination of the p-nitrophenol released by acid-phosphatase or β -glucosidase activity, respectively. Corresponding to findings of Skujins (1976), who revealed that toluene stops further enzyme synthesis reaction products by microorganisms during incubation time, no toluene was used. To determine the enzyme activity without toluene was supported by Bandick and Dick (1999) who analyzed the enzyme activity without toluene because of the short incubation time. In addition, Klose and Tabatabai (2002a, b) showed that the acid-phosphatase and glucosidase activity values of toluene-treated and untreated soil samples were not significantly different.

Acid-phosphatase (EC 3.1.3.2)¹

One gram of sieved and field moist soil, 4 ml modified universal buffer pH 6.5 (MUB)^{2a} and 1 ml of 0.05 M p-Nitrophenyl-phosphate solution³ were placed in a 50 ml Erlenmeyer flask and shaken at 60 rpm on a rotary shaker at 37 °C. After 60 minutes the reaction was stopped by addition of 1 ml 0.5 M CaCl₂ and 4 ml 0.5 M NaOH. The suspension was filtrated (Schleicher and Schuell, 595 ½) and 0.5 ml of the filtrate were diluted with 4.5 ml deionized H₂O. The filtrate absorbance was measured spectrophotometrically at 405 nm. The results are expressed in units of micrograms of p-nitrophenol (PN) released per gram soil (moisture free basis) per hour (µg g⁻¹ h⁻¹).

β-D-Glucosidase (EC 3.2.1.21)¹

One gram of sieved and field moist soil, 4 ml MUB pH 6.0^{2b} and 1 ml 0.05 M p-Nitrophenyl-β-D-glucoside⁴ were placed in a 50 ml Erlenmeyer flask and shaken at 37 °C and 60 rpm on a rotary shaker. After one hour the reaction was stopped by addition of 1 ml 0.5 M CaCl₂ and 4 ml 0.1 M TRIS (pH 12)⁵. The suspension was filtrated (Schleicher and Schuell, 595 ½) and 0.5 ml of the filtrate were diluted with 4.5 ml TRIS (pH 10)⁶ solution. The filtrate absorbance was measured spectrophotometrically at 405 nm. The results are expressed in units of micrograms of p-nitrophenol (PN) released per gram soil (moisture free basis) per hour (µg g⁻¹ h⁻¹).

¹ The Enzyme Commission (EC) numbers and enzyme names are according the recommendations by the Nomenclature Committee of the International Union of Biochemistry and Molecular Biology on the Nomenclature and Classification of Enzymes, (NC-IUBMB, 2006).

² 12.1 g tris (hydroxymethyl)-aminomethane, H₂NC(CH₂OH)₃, 11.6 g maleic acid, C₄H₄O₄, 14.0 g citric acid monohydrate, C₆H₈O₇·H₂O, 6.3 g boric acid, H₃BO₃, and 488 ml 1.0 M sodium hydroxide were put in a 1000 ml volumetric flask and filled up with deionized water.

^{a)} 200 ml MUB were placed in a 1000 ml Erlenmeyer flask and titrated with 1 M HCl to pH 6.5 and filled up with deionized water

^{b)} 200 ml MUB were placed in a 1000 ml Erlenmeyer flask and titrated with 1 M HCl to pH 6.0 and filled up with deionized water

³ 0.84 g C₆H₄NNa₂O₆P·6H₂O (4-Nitrophenyl phosphate Disodium salt Hexahydrat, were placed in a 50 ml Erlenmeyer flask and filled up with MUB pH 6.5

⁴ 0.654 g C₁₂H₁₅NO₈ (4-Nitrophenyl-β-D-glucopyranoside) were placed in a 50 ml Erlenmeyer flask and filled up with deionized water

⁵ 12.2 g H₂NC(CH₂OH)₃ (tris hydroxymethyl-aminomethane,) were placed in 1000 ml filled up with deionized water and titrated with 1 M NaOH to pH 12

⁶ 12.2 g H₂NC(CH₂OH)₃ (tris hydroxymethyl-aminomethane,) were placed in 1000 ml filled up with deionized water

3.6.1.2 Microbial carbon (C_{mic})

The soil microbial carbon content at the field and rainfall experiment was determined with the chloroform fumigation-extraction method (CFE) as described by Vance et al. (1987)⁷. Microbial carbon for the fumigated and unfumigated samples was analyzed with three replications per soil sample, each replicate consisting of 15 grams field moist soil sieved to 2 mm in a glass container. The containers for the fumigation were placed in a desiccator, which was lined with freshly moistened paper towels to get a full moisturized atmosphere. In addition to the soil samples 25 ml ethanol-free chloroform (822265, Merck Darmstadt) with a few boiling chips were placed into the desiccator. The desiccator was sealed and evacuated with a vacuum pump until the $CHCl_3$ boiled vigorously. The evacuated desiccator was placed in darkness at 25 °C for 24 hours. After the fumigation treatment the beaker of $CHCl_3$ and the moistened paper towels were removed. Afterwards, the desiccator was evacuated eight to ten times with a vacuum pump to remove all traces of chloroform from the soils⁸.

To extract the microbial biomass carbon of the fumigated (treated with chloroform) and unfumigated (field moist soil, not treated with chloroform) samples, 60 ml of 0.5 M K_2SO_4 were added and the samples were shaken for 30 minutes at 220 rpm. After shaking, the soil suspension was passed through a filter (Schleicher and Schuell, 595 ½). The filtrate was stored at -20 °C until the C content of the K_2SO_4 extracts was measured on a Shimadzu TOC 5000A soluble C analyzer. The microbial carbon was afterwards calculated as the difference between the amount of Dissolved Organic Carbon (D.O.C.) extracted from fumigated and unfumigated soil (Sparling and West, 1988; Tate et al., 1988; Vance et al., 1987), while the original scaling factor of 2.64 according to Vance et al. (1987) was used.

$$C_{mic} = (D.O.C._{\text{fumigated soil sample}} - D.O.C._{\text{unfumigated soil sample}}) \times K$$

D.O.C.: Dissolved Organic Carbon

K: 2.64 (factor according to Vance et al., 1987)

Results are expressed in $\mu\text{g } C_{mic}$ per g soil ($\mu\text{g g}^{-1}$); moisture free basis

⁷ The benefit of this method was shown by Kaiser et al. (1995) and Joergensen (1995) who revealed that this analyze is unaffected by soil water content.

⁸ After substrate addition the chloroform fumigation-extraction method should not be used directly, because of the elevated C contents the proportionality between chloroform-labile C and biomass C is not suitable (Witter and Dahlin, 1995)

3.6.2 Abiotic Indicators

3.6.2.1 Soil texture analysis

The soil particle size distribution of the Ap-horizon was analyzed according to the German DIN 19683 method (pipette method). The classification of the soil type was done according to the FAO classification system (FAO/ISRIC/ISSS, 1998).

3.6.2.2 Soil surface roughness

For characterization of the soils surface roughness images of the shaded surface of each inner core were taken weekly with a consumer digital camera (Olympus 5050zoom). For an easier post processing a frame with a scale reference system was added and located on the surface when the image was taken. In post processing the images of the soil surface were manipulated by image enhancement in image-editing software like Corel Photo Point © (Corel, Eden Prairie, USA). After enhancement the image was georeferenced in a Geographical Information System (GIS) in a local reference system. The second image enhancement was accomplished in the environment of the GIS. Adoptions of a high pass filter accentuate the borders of the soil aggregates. In this manipulated image, the soil aggregates larger than 100 mm² were defined, selected and manually digitized (Fig. 9). Throughout the GIS functionality, the size of the aggregates can be easily appropriated and the aggregation ratio can be determined according the following equation:

$$\text{Aggregation ratio [\%]} = \frac{\text{Aggregate area [cm}^2\text{]}}{\text{Total area [cm}^2\text{]}}$$

The standard error of this method was calculated after one picture was analyzed three times. The standard error was estimated with 0.5 %.

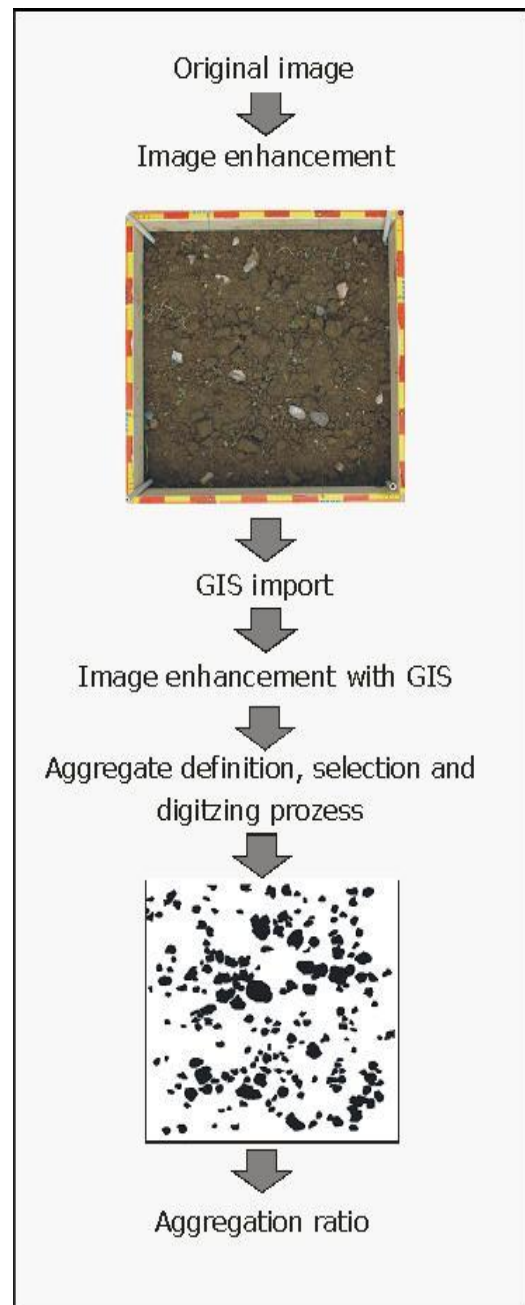


Fig. 9 Image processing from the original image to marked aggregates larger 100 mm² and aggregation ratio

3.6.2.3 Climate conditions

Precipitation

The quantity and the intensity of precipitation at the field experiment was measured one meter over soil surface level in between the three sites with a precipitation gage (Thies Clima, Göttingen, Germany). Data was collected at 30-minute intervals with a Delta-T logger (Delta-T Devices, Cambridge, UK).

Air and soil temperature

The air temperature data were taken from the climate station “Birkenmoor” of the Kiel University which is approximately 6 km in the north west of the farming station Lindhof (IPS, 2006). The soil temperature was measured 3 cm below the surface of each core plot of the field and laboratory rainfall experiment with PT100 sensors (SKYE, Landrindod Wells, UK). Data was collected at 30-minute intervals with a Delta-T logger (Delta-T Devices, Cambridge, UK). The 7 day floating soil temperature was calculated afterwards.

3.6.2.4 Organic Carbon (C_{org})

The total organic carbon content at the field and rainfall experiment was analyzed according to the German DIN ISO method 10694: 1995 for organic carbon at a C/N Analyzer “Elementar vario MAX CN” (Elementar, Hanau, Germany).

3.6.2.5 C_{mic}/C_{org} ratio

The ratio of microbial biomass C to soil organic C (% C_{mic}/C_{org}) is the microbial C content per unit soil carbon (Anderson and Domsch, 1989; Sparling, 1992).

The C_{mic}/C_{org} ratio [%] was calculated on the basis of the chloroform fumigation-extraction method (CFE) -derived microbial C and soil organic C content.

$$C_{mic}/C_{org} \text{ ratio } [\%] = C_{mic} \text{ content} / C_{org} \text{ content}$$

3.6.2.6 Nitrogen (N)

The total nitrogen content at the field and rainfall experiment was analyzed according to the German DIN ISO 13878: 1998 for total nitrogen (Dumas combustion method) at a C/N Analyzer “Elementar vario MAX CN” (Elementar, Hanau, Germany). The C/N ratio was calculated afterwards.

3.6.2.7 C/N ratio

The C/N ratio was calculated for each sampling time datasets obtained from the organic carbon and nitrogen analysis.

$$C/N \text{ ratio} = C_{\text{org content}} / N \text{ content}$$

3.6.2.8 pH-value

The soil pH at the field and rainfall experiment was measured according to the German DIN ISO 10390: 1997 method. To 20 gram 2 mm sieved air dry soil, 50 ml 0.01 M CaCl₂ was added and mixed. After 24 hours the pH-value was measured by using a glass combination electrode (WTW, Weilheim, Germany).

3.6.2.9 Soil water

Soil moisture content

The soil moisture content in the field and laboratory experiment in the upper 3 cm was gravimetrically measured from soil samples taken for the enzyme analysis. Furthermore the soil moisture was measured 30 cm below the soil surface (bs) with TDR probes in the rainfall experiment. These data was collected at 30-minute intervals with a Delta-T logger (Delta-T Devices, Cambridge, UK).

Matric potential

The soil matric potential three centimeters below the surface (bs) of each soil box at the laboratory rainfall experiment was measured with tensiometer probes (self constructed), equitensiometer probes (Ecomatic, Munich, Germany) and gypsum block sensors (Delta-T, Cambridge, UK). Data were collected at 30-minute intervals with a Delta-T logger (Delta-T Devices, Cambridge, UK). The probes were shown in Fig. 10.

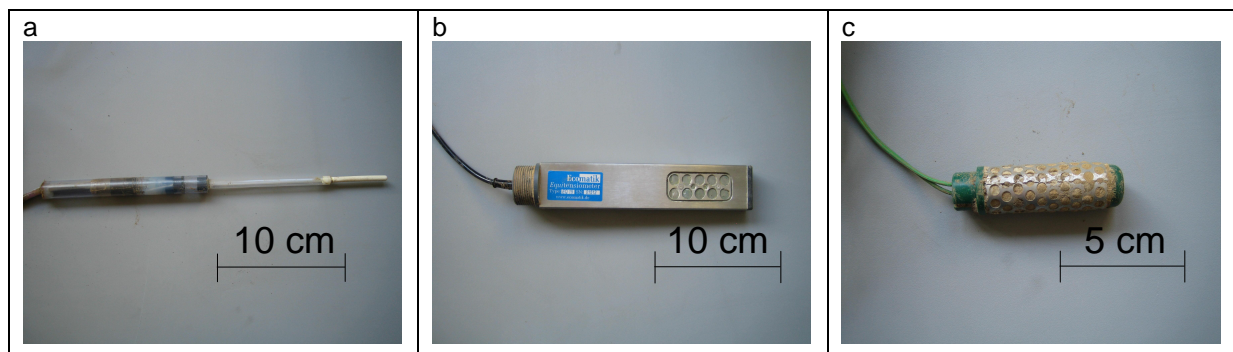


Fig. 10 Tensiometer probe (a), Equitensiometer probe (b) and gypsum block sensor (c) to measure the soil matric potential

3.6.2.10 Runoff

The runoff was only analyzed during the rainfall experiment. During each rainfall experiment the runoff of the inner core plot (40 x 50 cm) was measured with a precipitation gage (Thies Clima, Göttingen, Germany) in six minutes intervals. Afterwards the runoff was converted into the unit “runoff as % of rainfall” according the following equation:

$$\text{Runoff [\%] per } m^2 = (\text{Runoff in ml} * f * 100) / b$$

$f = 4.16$ (Calculation factor from the measured 40 * 50 cm rectangle to m^2)

$b = 1500$ (calculation factor for total rainfall in 6 minutes on one m^2)

3.7 Statistical analysis

The correlation as well as the regression analysis was performed by using the SAS linear regression procedure (SAS Institute, 1999) to reveal possible interaction between the enzyme activities (acid-phosphatase, β -glucosidase) and the measured soil biotic and abiotic parameters. The aggregation ratio was tested in the same way to find possible correlations to the biotic and abiotic parameters, as well. The Pearson's correlation coefficient R^9 was used to describe the degree of the linear association between two variables. In addition to R the significance level as expressed as P value was used to reveal how likely the correlation is to be not true (e.g. $P < 0.01$ is meaning that the finding has a one percent chance of not being true).

The level of significance was divided into four categories

- *** $P < 0.001$
- ** $P < 0.01$
- * $P < 0.05$
- n.s. not significant

The best approach from a statistical point of view is to repeat the study and see if the results are the same. If something is statistically significant in two separate studies, it is probably true. Therefore the experimental periods 2004 and 2005 were used as treatment replication and in the second consideration as one continuous treatment.

⁹ The R value ranges from -1.0 to +1.0. The closer R is to +1 or -1, the more closely the two variables are related. If R is close to 0 it means there is no relationship between the variables. If R is positive, it means that as one variable gets larger the other gets larger as well. If R is negative it means that if one gets larger, the other gets smaller (inverse correlation).

Furthermore the datasets of all measured variables were shown in Box-Whisker-Plots by using the STATISTICA[®] program to expose the mean square, mean deviation as well as the dataset range at the three different management systems.

In addition the analysis of variance (ANOVA) by using STATISTICA[®] was performed to test the null hypothesis that the biotic and abiotic parameters at the different management systems (Old Organic Farming, Young Organic Farming and Conventional Farming) are equal.

$$H_0: MS_1 = MS_2 = MS_3$$

H_0 : null hypothesis

MS : management system

Additionally an explorative statistical method (visual assessment) was used to describe the soil surface of the core plots in the field as well as in the rainfall experiment.

4 Results

In this chapter first of all the soil texture of the study sites in the field as well as at the rainfall experiment are shown. Thereafter the results of the biotic and abiotic investigations as well as of the image analysis are presented for the Old Organic Farming site, Young Organic farming site and for the Conventional Farming site during the field experiment. Afterwards the results of the biotic, abiotic, image analysis as well as of the runoff data derived at the laboratory rainfall experiment are shown in the sequence Old Organic Farming soil, Young Organic Farming soil and Conventional Farming soil.

4.1 Soil texture

The soil texture of the Old Organic Farming (OOF), Young Organic Farming (YOF) and Conventional Farming (CF) sites was loamy sand. The soil type according the FAO soil classification system (FAO/ISRIC/ISSS, 1998) was a Luvisol. The data obtained for the Ap-horizon at the field experimental sites were transferable to the soils used at the rainfall experiment because the soil sampling was accomplished at the same sites and sectors where the field experiment was conducted. The particle size distribution of the Ap-horizon at the two organic and one conventional farming site is shown in detail in Table 4.

Table 4 Soil texture of the Ap-horizon of the OOF, YOF and CF site*

site	soil texture**	coarse sand %	medium sand %	fine sand %	total sand %	coarse silt %	medium silt %	fine silt %	total silt %	clay %
OOF	SI3	4.7	23.19	40.71	68.59	9.6	7.46	4.26	21.32	10.1
YOF	SI4	3.85	16.92	34.71	55.49	13.1	10.77	6.01	29.88	14.63
CF	SI3	3.66	19.59	38.14	61.39	12.92	9.23	4.63	26.78	11.83

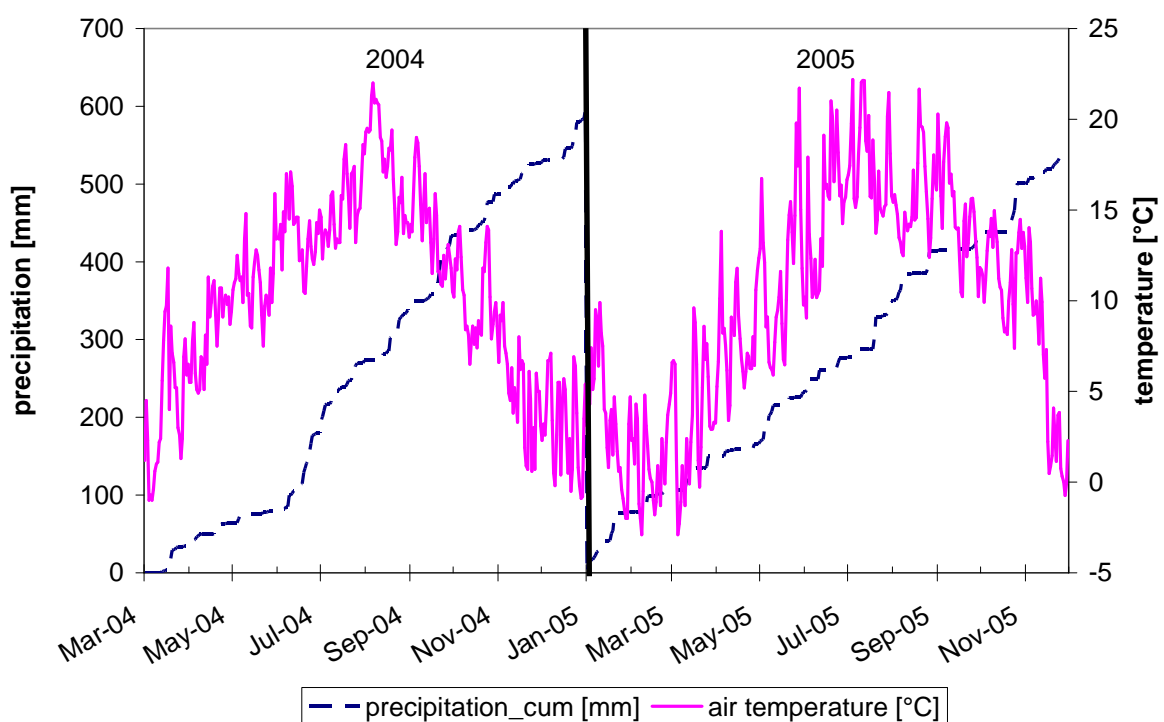
* in the field and rainfall experiment

** Soil texture description according to Eckelmann (2005)

4.2 Field experiment

Environmental conditions

In the field experiment the climate conditions such as air temperature and precipitation (measured at the OOF site which was in the middle of the YOF and CF sites) were recorded beginning at March 2004 until December 2005 and shown in Fig. 11. The air temperature ranged during the whole period between -3.0 °C and +22.0 °C, the cumulative rainfall was 579 mm beginning from March to the end of December 2004 and 536 mm for the whole year 2005, whereas the precipitation at the end of January and February (2005) has fallen as snow and covered the soil surface with a 10 to 20 cm thick layer.



* starting at March 2004

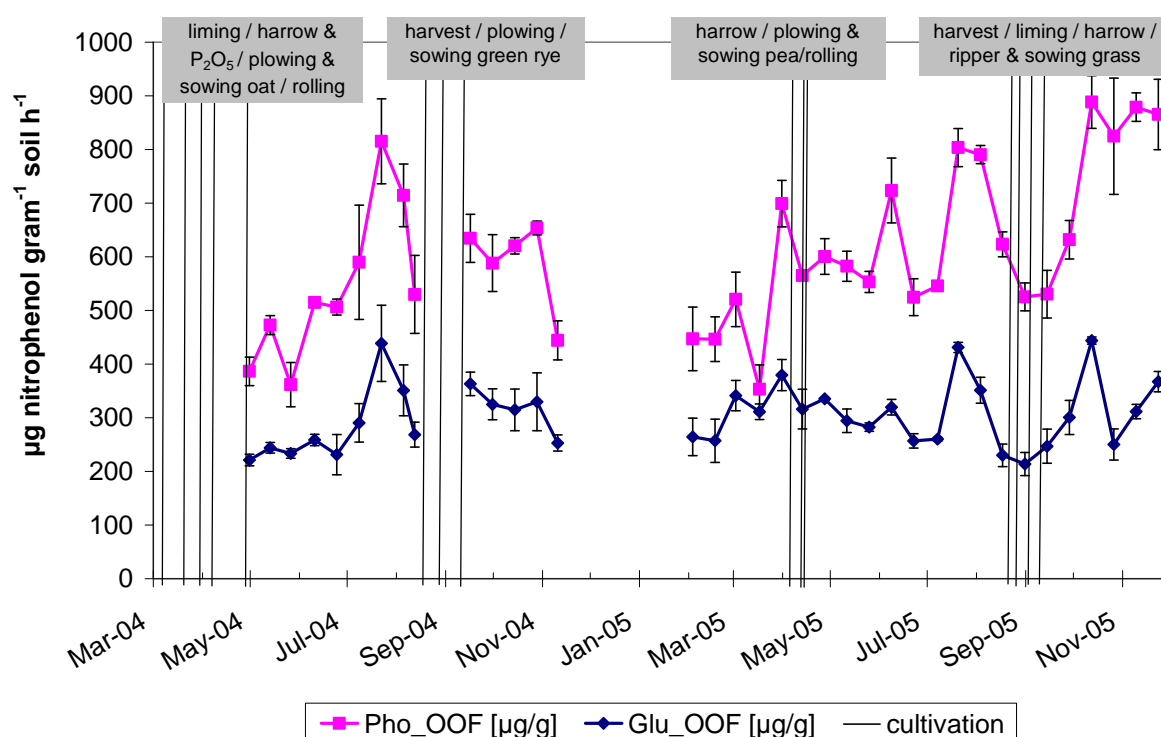
Fig. 11 Air temperature as well as cumulative precipitation in the year 2004* and 2005

4.2.1 Old Organic Farming site

4.2.1.1 Enzyme activity

At the Old Organic Farming site (OOF) the activity of acid-phosphatase ranged from 353 to 888 μg nitrophenol (NP) released in one hour (μg NP/g*h) with an arithmetic mean of 585 μg NP/g*h and a mean deviation of 116 μg NP/g*h. The activity of β -glucosidase (Glu) changed between 221 and 441 μg NP/g*h. The arithmetic mean is 297 μg NP/g*h and the standard deviation 49 μg NP/g*h. In early March 2004 soil cultivation practices at the OOF site include lime (CaCO_3) and phosphate (P_2O_5) application, harrow disking, plowing, sowing oat and rolling the soil. After the seedbed was fully prepared the enzyme activity at the first sampling (30-April-2004) was 386 μg NP/g*h for acid-phosphatase and 221 μg NP/g*h for

β -glucosidase. Beginning at the third sampling (26-May) the enzyme activity rose stepwise until 22-July to 815 $\mu\text{g NP/g}^*\text{h}$ for acid-phosphatase and 438 $\mu\text{g NP/g}^*\text{h}$ for β -glucosidase. After this point, the activity decreased at the next two sampling times strongly and stepwise to 529 $\mu\text{g NP/g}^*\text{h}$ for acid-phosphatase and 268 $\mu\text{g NP/g}^*\text{h}$ for β -glucosidase until the harvest. After plowing and sowing green rye the sampling process started for the fall vegetation period (beginning 16-September-2004) with higher enzyme activity levels than at the end of the summer vegetation period. The acid-phosphatase as well as the β -glucosidase activity showed at the last sampling in November-2004 reduced activity values with 444 $\mu\text{g NP/g}^*\text{h}$ for acid-phosphatase and 252 $\mu\text{g NP/g}^*\text{h}$ for β -glucosidase compared to the previous enzyme activity in fall 2004 (Fig. 12).



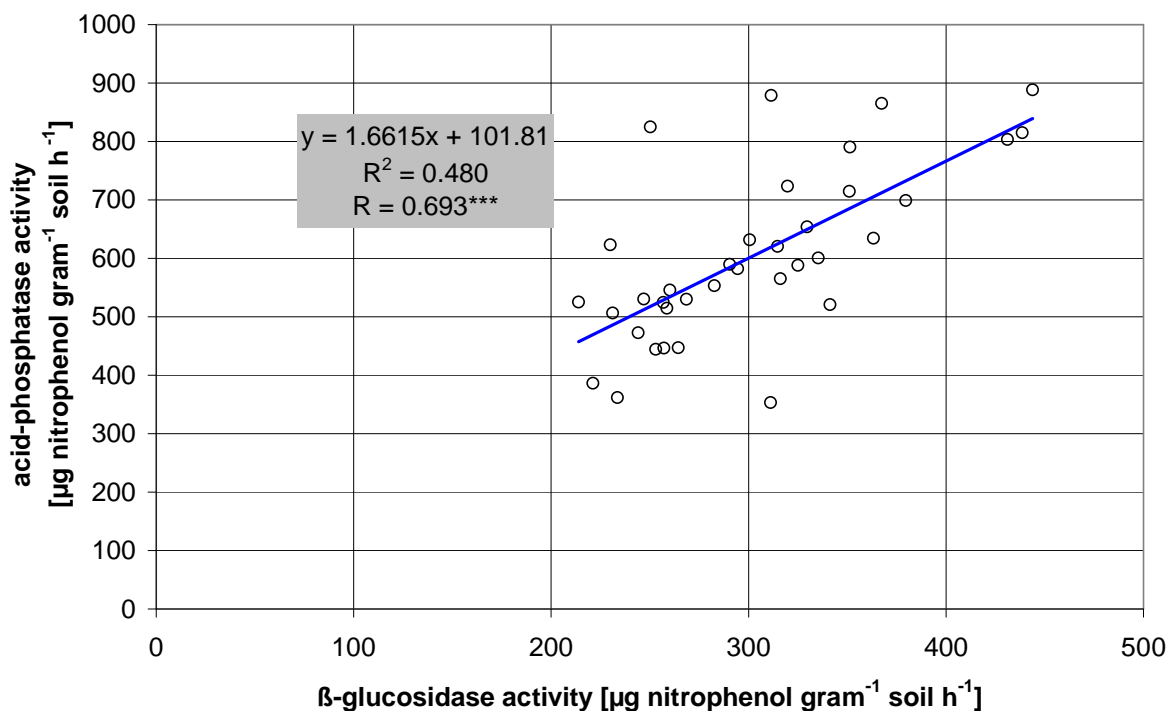
Error bars indicate the standard deviation between 9 replications

Fig. 12 Enzyme activity of acid-phosphatase (Pho), β -glucosidase (Glu) and cultivation practices at the OOF site in 2004 and 2005

In 2005 the enzyme activity of acid-phosphatase and β -glucosidase started at the first sampling time in 2005 (02-February) approximately at the same level compared to the last sampling at 10-November-2004. The enzyme activities increased at the third sampling (02-March) to 520 $\mu\text{g NP/g}^*\text{h}$ for acid-phosphatase and 341 $\mu\text{g NP/g}^*\text{h}$ for β -glucosidase, and decreased thereafter and rose two weeks later to 699 $\mu\text{g NP/g}^*\text{h}$ for acid-phosphatase and 379 $\mu\text{g NP/g}^*\text{h}$ for β -glucosidase. In the summer period 2005 both enzymes showed large dynamic changes with high activity values at 08-June and 20-July and decreased subsequent until the end of August. Subsequently the enzyme activity rose after harrow disk and ripper cultivation as well as sowing grass (as intercrop) stepwise to 888 $\mu\text{g NP/g}^*\text{h}$ for

acid-phosphatase and 443 $\mu\text{g NP/g}\cdot\text{h}$ for β -glucosidase. Thereafter the activity of acid-phosphatase stayed at a more or less constant value but the β -glucosidase activity showed at the last three samplings large activity value changes with low values of 250 $\mu\text{g NP/g}\cdot\text{h}$ and high values of 367 $\mu\text{g NP/g}\cdot\text{h}$.

In general the activity of β -glucosidase showed nearly the same dynamic patterns as the acid-phosphatase during the whole experimental period. The regression analysis showed therefore a positive significant correlation at the $P < 0.001$ level with a coefficient of determination $R^2 = 0.480$ and a correlation coefficient of $R = 0.69$ (Fig. 13).

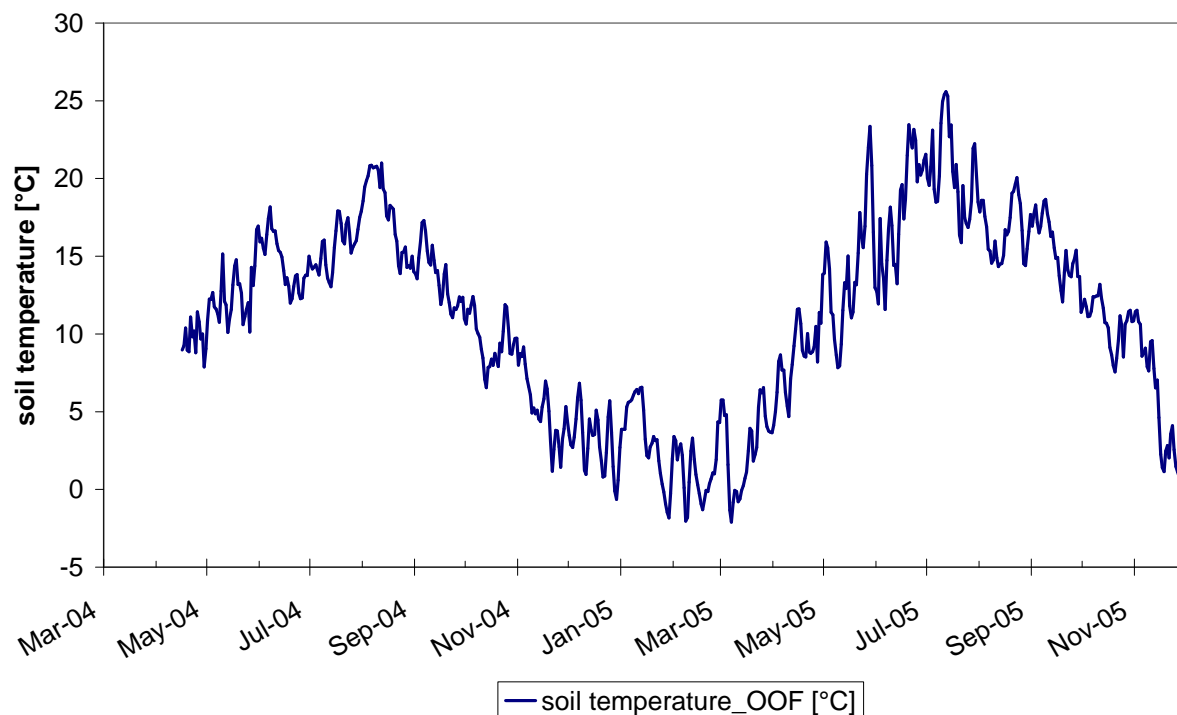


Level of significance: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, n.s. not significant, respectively

Fig. 13 Relationship between acid-phosphatase and β -glucosidase activity at the OOF site in 2004 and 2005

4.2.1.2 Soil temperature

The soil temperature at the OOF site was shown in Fig. 14 as a seven day moving average. In 2004 the soil temperature 3 cm below the soil surface increased until 12-August-2004 and decreased stepwise to -2.0 $^{\circ}\text{C}$ in early January. In late January the precipitation has fallen as snow and covered the soil surface until late February with a layer of 10 to 20 cm thickness. After the snow thawed the soil temperature rose in general (with dynamic changes) to 25.3 $^{\circ}\text{C}$ at mid of July. Thereafter the soil temperature showed a decreasing trend until winter 2005.



* seven day moving average

Fig. 14 Soil temperature* 3 cm below the soil surface at the OOF site in 2004 and 2005

4.2.1.3 Carbon

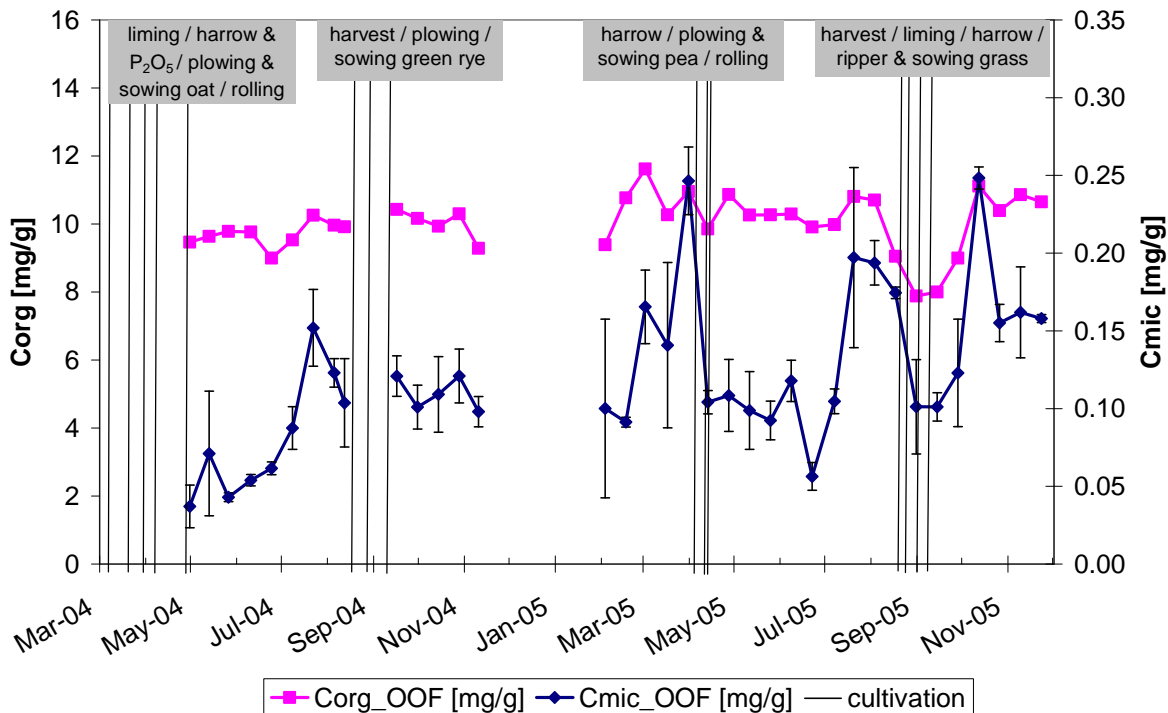
Organic carbon (Corg)

At the first sampling time at 30-April-2004 the organic carbon (Corg) content was 9.50 mg/g and showed an increasing tendency with exceptions in June and at the last sampling in November. In 2005 the Corg content started at the first sampling time in 2005 (02-February) approximately at the same level compared to the last sampling in November-2004. In spring 2005 the organic carbon content showed dynamic changes between 9.4 mg/g and 11.6 mg/g and was nearly stable in the summer period 2005. In early August the organic carbon decreased stepwise until end of August (minimum 7.9 mg/g) and increased in the followed weeks after cultivation to 11.1 mg/g until 12-October and showed thereafter weak dynamic changes (Fig. 15).

Microbial carbon (Cmic)

The microbial carbon (Cmic) content in spring 2004 was 0.037 mg/g and showed an increasing tendency until 22-July (0.152 mg/g) and decreased thereafter stepwise until 12-August to 0.104 mg/g. After harvest, plowing and sowing the microbial carbon content ranged between 0.101 mg/g and 0.121 mg/g. Regarding the errors bars in the year 2004 the microbial carbon showed in the late summer and fall period only weak dynamic changes. In 2005 the Cmic content started approximately at the same level such as at the last sampling in November-2004 and rose in the following weeks to 0.247 mg/g. Subsequent to the spring

cultivation the Cmic content showed a decreasing tendency until end of June and increased stepwise to around 0.200 mg/g until end of July. After fall cultivation in 2005 the Cmic showed low contents (0.100 mg/g) and increased stepwise in the following six weeks to 0.248 mg/g and decreased thereafter to 0.155 mg/g and stayed at this level until the last sampling (Fig. 15).



Error bars indicate the standard deviation between 3 replications (not visible for Corg)

Fig. 15 Organic carbon (Corg) content, microbial carbon (Cmic) content, as well as cultivation practices at the OOF site in 2004 and 2005

Cmic/Corg ratio

At the first sampling in spring 2004 the Cmic/Corg ratio was 0.39 % (as % Cmic of Corg) and showed thereafter a general increase until 22-July-2004 (1.48 %) and decreased thereafter stepwise in the following four weeks. After harvest, plowing and seeding the Cmic/Corg ratio showed in fall only weak dynamic changes around the 1.00 % level. In 2005 the Cmic/Corg ratio was more or less the same value compared to the last sampling in November-2004. Thereafter the Cmic/Corg ratio showed an increasing tendency until end of March (2.25 %), decreased after spring cultivation (with one exception at 08-June) until 22-June-2005 (0.57 %) and increased subsequently until mid of August. After fall cultivation the Cmic/Corg ratio decreased again but increased in the following weeks to 2.23 % at 12-October (Fig. 16).

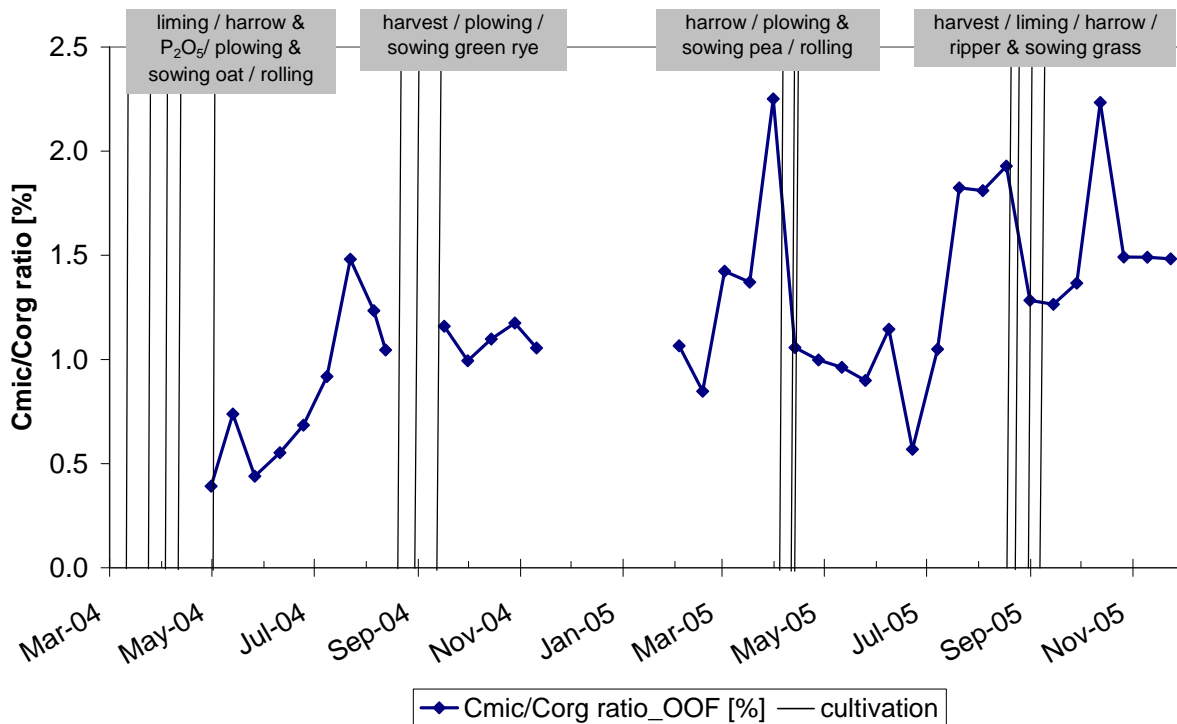
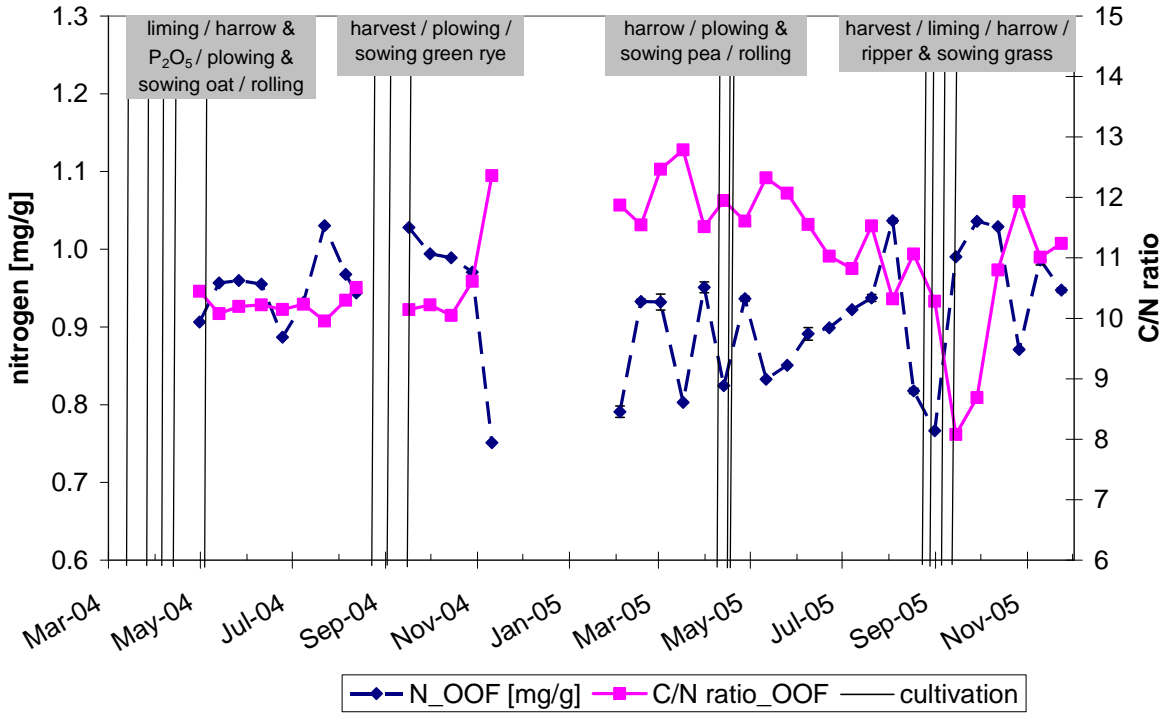


Fig. 16 Cmic/Corg ratio as well as cultivation practices at the OOF site in 2004 and 2005

4.2.1.4 Nitrogen and C/N ratio

The nitrogen content ranged between spring cultivation and harvest 2004 among 0.89 mg/g and 1.03 mg/g. After plowing and sowing, the nitrogen content was 1.03 mg/g and decreased stepwise until 10-November-2004 to 0.75 mg/g (with an immense decrease at the last sampling). At the first sampling in 2005 the nitrogen content was comparable to the value reached at the last sampling in 2004 and showed thereafter dynamic changes between 0.95 and 0.80 mg/g until May. In the summer period the nitrogen content increased stepwise from 0.83 to 1.04 mg/g at early August followed by a sharp decrease. After fall cultivation the nitrogen content increased again and showed more or less intense dynamic changes until end of 2005 (Fig. 17).

The C/N ratio in 2004 ranged between 9.95 and 10.51 and rose at end of 2004 to 12.36. The statistical mean in 2004 was 10.91. In 2005 the C/N ratio showed more or less the same value as at the last sampling in 2004. From May to September the C/N ratio showed a decreasing trend and an increasing tendency thereafter. The dynamic changes in 2005 are between 12.79 and 8.08 with a statistical mean of 11.20 (Fig. 17).



Error bars indicate the standard deviation between 3 replications (mostly not visible at this scale)

Fig. 17 Nitrogen content, C/N ratio and cultivation practices at the OOF site in 2004 and 2005

4.2.1.5 pH-value

The pH-value ranged between pH 6.5 and pH 6.0 with an average pH-value of 6.3 in 2004 and among pH 5.5 and pH 6.8 with a mean pH-value of 6.1 in the experimental period 2005 (Fig. 18).

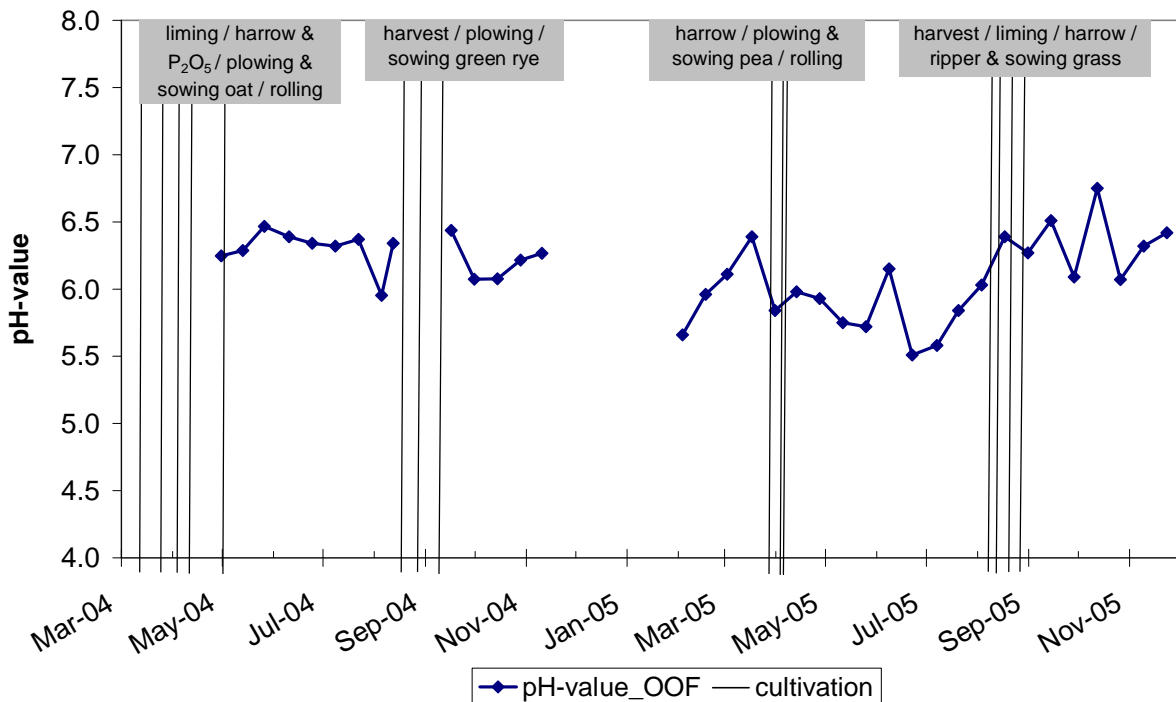


Fig. 18 pH-value and cultivation practices at the OOF site in 2004 and 2005

4.2.1.6 Soil moisture content

In 2004 the water content at the OOF site ranged between dry conditions (e.g. 2.6 %) in spring and summer 2004 and moist conditions (e.g. 18.1 %) in June and fall. In 2005 the soil moisture was high in early February and decreased in the followed weeks. In July the moisture content increased and showed dry as well as moist conditions in fall 2005 (Fig. 19).

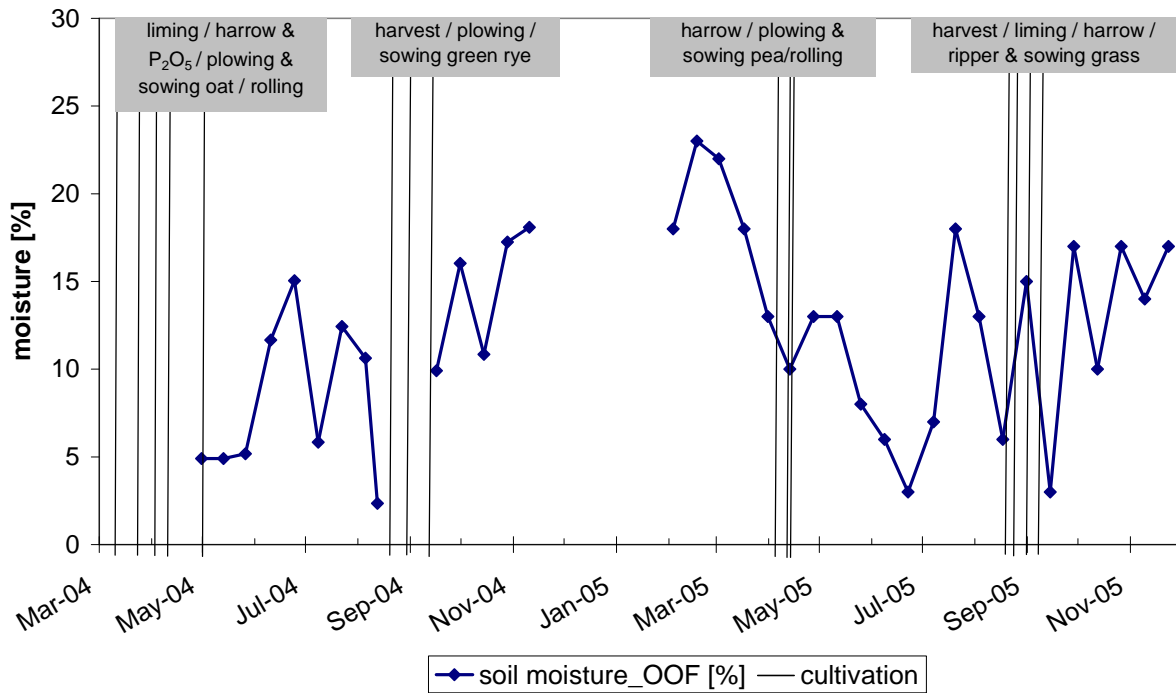


Fig. 19 Soil moisture content in the upper 3 cm of the OOF soil samples as well as cultivation practices in 2004 and 2005

4.2.1.7 Soil surface roughness

The image analysis 2004 started according to the soil sampling intervals for the biotic and abiotic analysis after sowing at 30-April until 12-August-2004. The initial aggregation ratio was 34.1 % and decreased after 16 mm precipitation with a maximum intensity of 2.7 mm per hour to 27.0 %. After 23.8 mm additional precipitation with an intensive rainfall event at 09-June-2004 (14.1 mm precipitation in 2 hours and a maximum intensity of 4.5 mm per hour) the aggregation ratio decreased to 21.8 %. In the following two weeks the precipitation sum was 56.4 mm (with 42.5 mm precipitation between 17 and 24-June and a maximum intensity of 4.5 mm per hour) and the aggregation ratio declined to 15 %, furthermore first crusting signs were visible. Until the next image analysis the aggregation ratio declined to 13.5 % after a total rainfall sum of 159.3 mm. Subsequently to 44 mm precipitation (total precipitation: 203.7 mm) with a maximum intensity of 5.3 mm/h the aggregation ratio declined to 9.3 %. After a rainfall event with an intensity of 13.5 mm precipitation per hour the aggregation ratio was 2.0 % at the OOF site at 05-August-2004 with clear visible crusting signs on the soil surface (Fig. 20). The image analysis stopped at 05-August-2004 at the organic farming site because of the following harvest and fall cultivation practices.

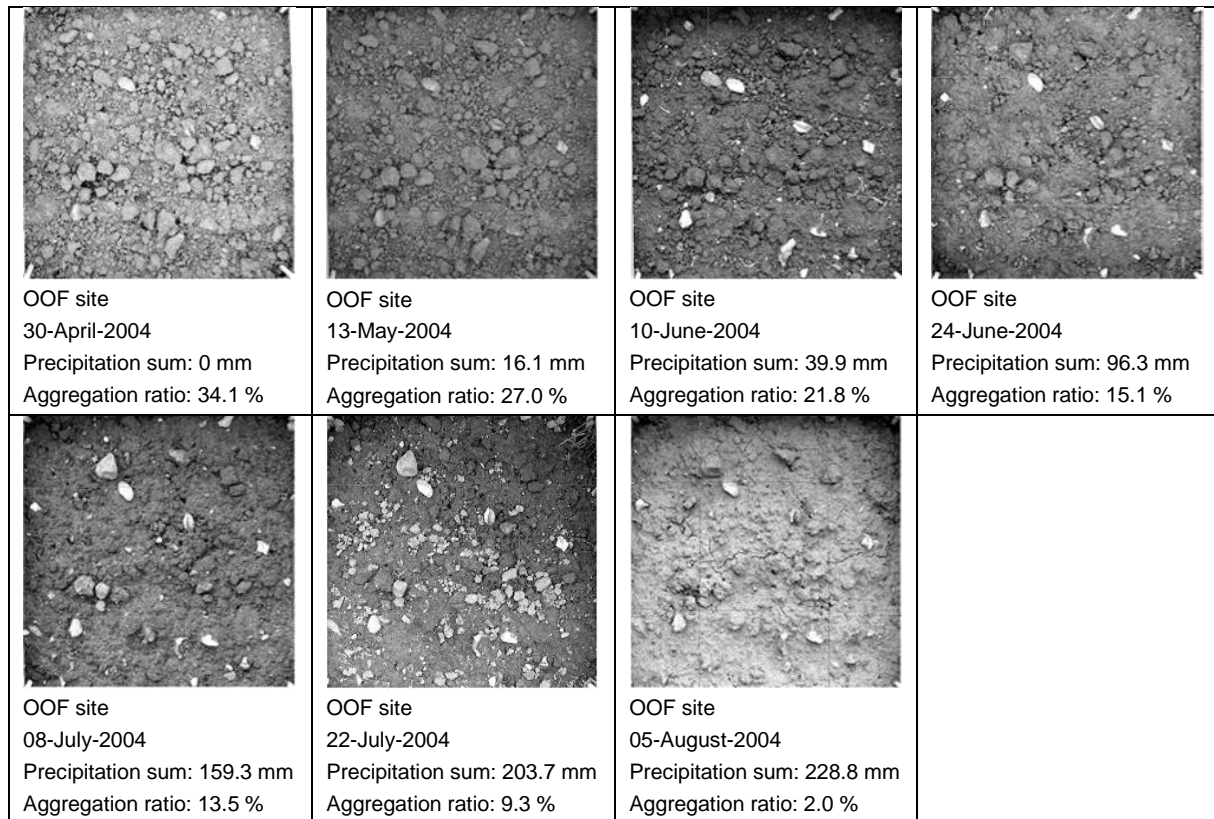


Fig. 20 Image sequence of the inner core unit at the OOF site, beginning at 30-April-2004 until 05-August-2004

To make the dynamic processes at the soil surface in 2004 more visible the aggregation ratio in combination with the precipitation sum is shown in Fig. 21.

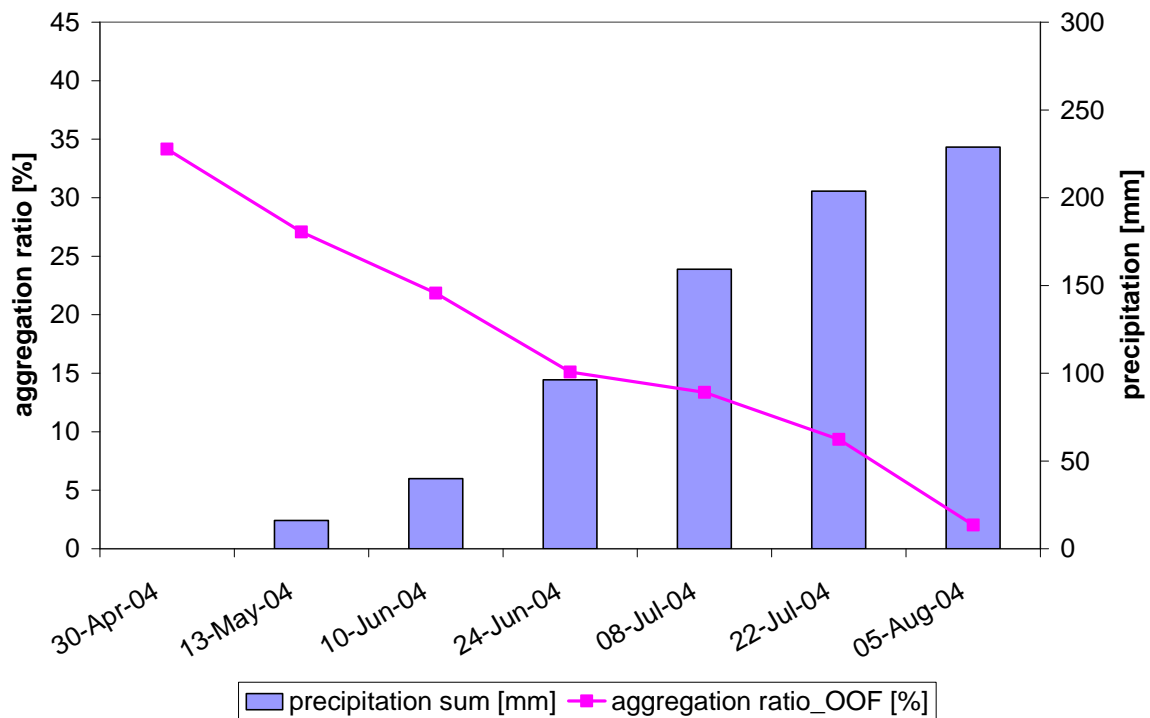


Fig. 21 Precipitation sum and aggregation ratio at the OOF site, beginning at 30-April-2004 until 05-August-2004

In 2005 the image analysis started at 13-April after harrow disk cultivation, plowing, sowing pea and rolling. The initial aggregation ratio was 39.5 %. After 57.5 mm precipitation (maximum intensity: 5.8 mm/h) the aggregation ratio decreased to 25.9 % at 11-May and to 23.6 % after 68.1 mm total precipitation. After 23.4 mm additional rainfall (total precipitation: 91.5 mm; maximum precipitation: 2.6 mm/h) the aggregation ratio decreased to 7.0 % at 08-June-2005 and the soil surface showed a visible soil surface crusting. In the following weeks the aggregation ratio declined to 6.6 % at 07-July (total precipitation: 129.3; maximum precipitation: 4.5 mm/h) and to 1.9 % after 145.6 mm total precipitation with a maximum intensity of 12.7 mm/h. At 03-August the aggregation ratio increased to 8.5 % (precipitation sum: 225.6 mm; maximum precipitation intensity: 5.1 mm/h) and showed an aggregation ratio of 8.1 % at 17-August-2005 after 259.7 mm total precipitation with a maximum intensity of 10.6 mm/h. The visual assessment of the soil surface revealed that after 68.1 mm precipitation first crusting signs were visible which were fully distinct at 8-June and clearly visible until 17-August (Fig. 22).

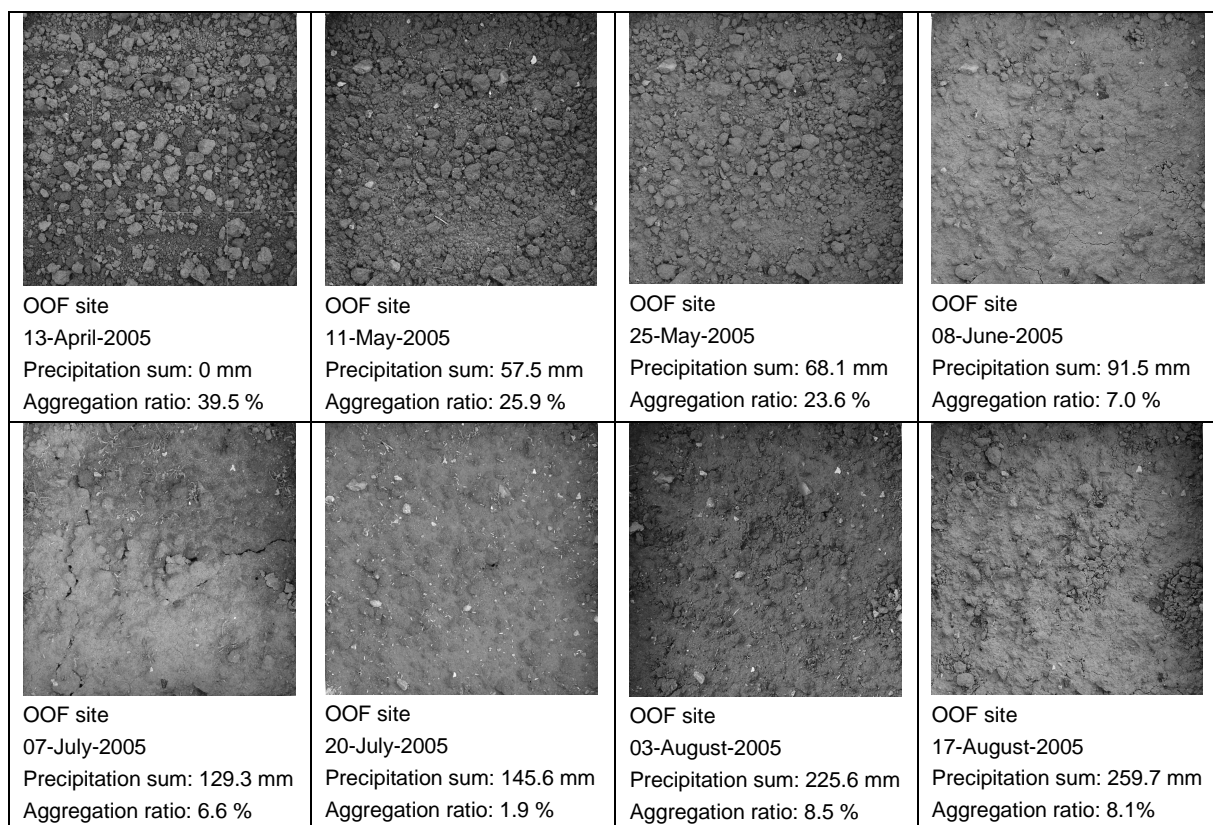


Fig. 22 Image sequence of the inner core unit at the OOF site, beginning at 13-April-2005 until 17-August-2005

Additional to the image design (Fig. 22) the aggregation ratio in combination with the precipitation sum is shown in Fig. 23.

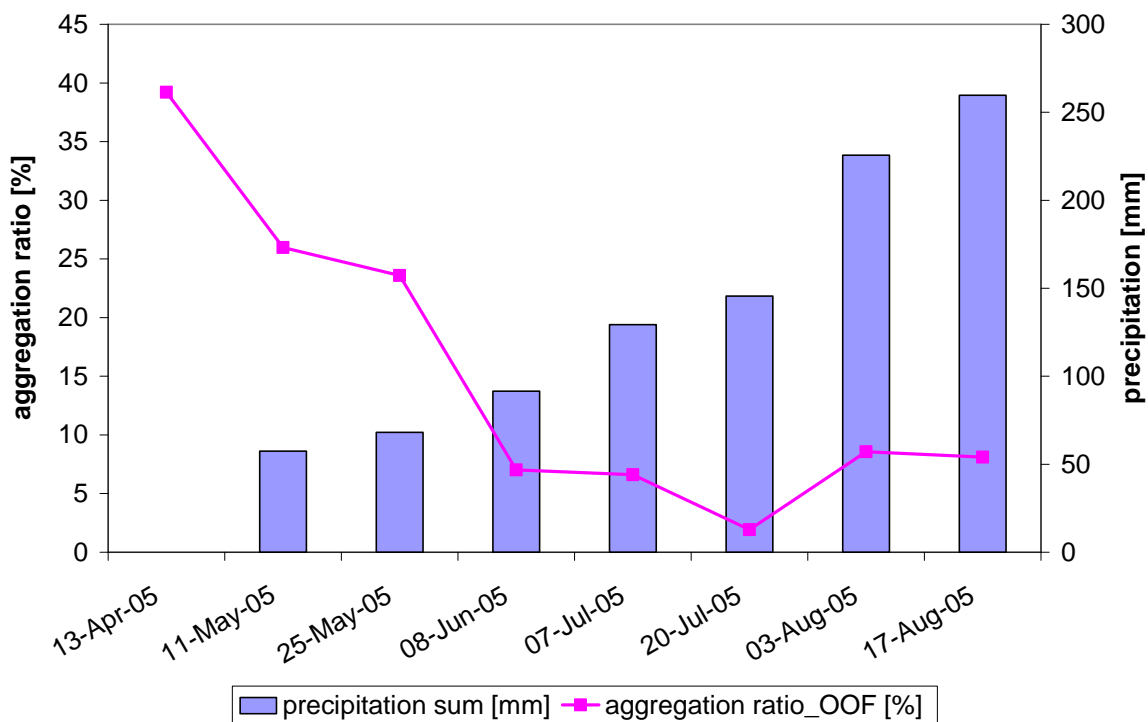


Fig. 23 Precipitation sum and aggregation ratio at the OOF site in 2005

4.2.1.8 Correlation statistics

The correlation coefficients (R) and significance levels between the enzyme activities and biotic as well as abiotic factors were shown for the experimental period 2004, 2005 as well as for the combined 2004/2005 period. The aggregation ratio showed negative significant correlations to the enzyme activities with one exception for β -glucosidase in the year 2005 where no significant correlation could be found. The factors Corg and Cmic content, Cmic/Corg ratio and the nitrogen content showed in general a positive and significant correlation to the enzyme activities of acid-phosphatase and β -glucosidase. The other factors such as C/N ratio, pH-value, soil moisture content, soil temperature (as seven day moving average) and the precipitation sum showed mostly no significant correlations to the enzyme activities but however with some exceptions (Table 5).

Table 5 Correlation coefficients (R)^a between enzyme activities^b and biotic and abiotic parameters^c at the OOF site for 2004, 2005 and 2004/2005

variable	site	acid-phosphatase			β-glucosidase		
		2004	2005	2004/2005	2004	2005	2004/2005
aggregation ratio	OOF	-0.864***	-0.620***	-0.715***	-0.725***	-0.218 ^{n.s.}	-0.461**
Corg	OOF	0.634***	0.390**	0.445**	0.770***	0.614***	0.600***
Cmic	OOF	0.892***	0.645***	0.720***	0.901***	0.717***	0.718***
Cmic/Corg ratio	OOF	0.876***	0.575**	0.677***	0.869***	0.563***	0.622***
nitrogen	OOF	0.577***	0.567***	0.488**	0.628***	0.524**	0.512**
C/N ratio	OOF	0.314 ^{n.s.}	0.106 ^{n.s.}	0.030 ^{n.s.}	0.266 ^{n.s.}	0.176 ^{n.s.}	0.102 ^{n.s.}
pH-value	OOF	-0.328 ^{n.s.}	0.339*	0.097 ^{n.s.}	-0.213 ^{n.s.}	0.203 ^{n.s.}	0.057 ^{n.s.}
moisture	OOF	0.327 ^{n.s.}	0.039 ^{n.s.}	0.120 ^{n.s.}	0.305 ^{n.s.}	0.213 ^{n.s.}	0.260 ^{n.s.}
temp	OOF	0.510**	0.282 ^{n.s.}	0.249 ^{n.s.}	0.416**	0.104 ^{n.s.}	0.011 ^{n.s.}
precipitation sum	OOF	0.440**	0.693***	0.474**	0.468**	0.006 ^{n.s.}	0.179 ^{n.s.}

^a Level of significance: * P <0.05, ** P <0.01, *** P <0.001, n.s. not significant

^b Acid-phosphatase, β-glucosidase

^c Aggregation ratio, organic carbon content (Corg), microbial carbon content (Cmic), Cmic/Corg ratio, nitrogen content, C/N ratio, pH-value, soil moisture content (moisture), soil temperature as seven day moving average (temp) and precipitation sum

Significance levels as well as correlation coefficients (R) between the aggregation ratio and biotic and abiotic factors were shown in Table 6. Negative significant correlations at the P<0.001 and P<0.01 level could be found to the acid-phosphatase activity, β-glucosidase (with an exception in 2005), Cmic content, Cmic/Corg ratio, nitrogen content, soil temperature (as seven day moving average) and the total precipitation sum. The C/N ratio showed positive significant correlation with the aggregation ratio at the P<0.05 level in 2004 and 2005 but no significant correlation in 2004/2005. The pH-value was furthermore positive correlated in 2004 to the aggregation ratio and not significant correlated in 2005 and 2004/2005. The soil moisture content showed in 2004 a negative significant correlation and no significant correlations in 2004 and 2004/2005.

Table 6 Correlation coefficients (R)^a between the aggregation ratio and biotic and abiotic parameters^b at the OOF site for 2004, 2005 and 2004/2005

variable	site	Aggregation ratio		
		2004	2005	2004/2005
Pho	OOF	-0.864***	-0.620***	-0.715***
Glu	OOF	-0.725***	-0.218 ^{n.s.}	-0.461**
Corg	OOF	-0.398*	-0.299*	-0.318*
Cmic	OOF	-0.808***	-0.633***	-0.645***
Cmic/Corg	OOF	-0.831***	-0.542**	-0.617***
nitrogen	OOF	-0.439**	-0.625***	-0.487**
C/N ratio	OOF	0.337*	0.397*	0.134 ^{n.s.}
pH-value	OOF	0.410**	0.008 ^{n.s.}	0.143 ^{n.s.}
moisture	OOF	-0.560**	0.061 ^{n.s.}	-0.273 ^{n.s.}
temp	OOF	-0.892***	-0.877***	-0.862***
precipitation sum	OOF	-0.958***	-0.742***	-0.832***

^a Level of significance: * P <0.05, ** P <0.01, *** P <0.001, n.s. not significant

^b Acid-phosphatase (Pho), β -glucosidase (Glu), organic carbon content (Corg), microbial carbon content (Cmic), Cmic/Corg ratio, nitrogen content, C/N ratio, pH-value, soil moisture content (moisture), soil temperature as seven day moving average (temp) and precipitation sum

4.2.2 Young Organic Farming site

4.2.2.1 Enzyme activity

The results for the enzyme activities at the Young Organic Farming (YOF) site were approached to the results at the Old Organic Farming (OOF) site. In Fig. 24 the enzyme activities of acid-phosphatase and β -glucosidase were shown in the summer and fall vegetation periods 2004 as well as from the early February 2005 till the late November 2005 regardless to the vegetation periods. The activity of acid-phosphatase in the experimental period 2004 and 2005 was between 624 $\mu\text{g NP/g}^*\text{h}$ and 263 $\mu\text{g NP/g}^*\text{h}$ with a statistical mean of 490 $\mu\text{g NP/g}^*\text{h}$ and a mean deviation of 69 $\mu\text{g NP/g}^*\text{h}$. The β -glucosidase activity ranged between 190 and 361 $\mu\text{g NP/g}^*\text{h}$, the statistical mean was 273 $\mu\text{g NP/g}^*\text{h}$ with a mean deviation of 31 $\mu\text{g NP/g}^*\text{h}$.

At the YOF site the first soil sample was taken at 30-April-2004 after harrow disk cultivation, plowing and sowing oat. The activity of acid-phosphatase was at the first sampling date 363 $\mu\text{g NP/g}^*\text{h}$ and raised two weeks later to 412 $\mu\text{g NP/g}^*\text{h}$ and decreased thereafter to

263 $\mu\text{g NP/g}^*\text{h}$. After this rapid decrease the activity enlarged in the following eight weeks to 617 $\mu\text{g NP/g}^*\text{h}$ till 05-August-2004 and fell down to 462 $\mu\text{g NP/g}^*\text{h}$ at the last sampling date in the summer vegetation period at 12-August-2004. The enzyme activity of β -glucosidase showed nearly the same dynamic changes as the acid-phosphatase activity in the summer vegetation period 2004. The lowest enzyme activity could be found at 26-May and the highest was found at 05-August-2004 (370 $\mu\text{g NP/g}^*\text{h}$) and decreased subsequent until the last summer sampling time 2004 (12-August) to 268 $\mu\text{g NP/g}^*\text{h}$. After harvest at 17-August-2004, plowing and sowing green rye the soil sampling started at 08-September for the fall vegetation period with an activity rate of 621 $\mu\text{g NP/g}^*\text{h}$ for acid-phosphatase and 306 $\mu\text{g NP/g}^*\text{h}$ for β -glucosidase. The activities decreased in the following four weeks to 539 $\mu\text{g NP/g}^*\text{h}$ for acid-phosphatase and to 261 $\mu\text{g NP/g}^*\text{h}$ for β -glucosidase, but rose at 14-October to 604 $\mu\text{g NP/g}^*\text{h}$ for acid-phosphatase and 299 $\mu\text{g NP/g}^*\text{h}$ for β -glucosidase. The activities of both enzymes were reduced stepwise in the following two sampling times to 508 $\mu\text{g NP/g}^*\text{h}$ for acid-phosphatase and 241 $\mu\text{g NP/g}^*\text{h}$ for β -glucosidase at 11-November-2004 (Fig. 24).

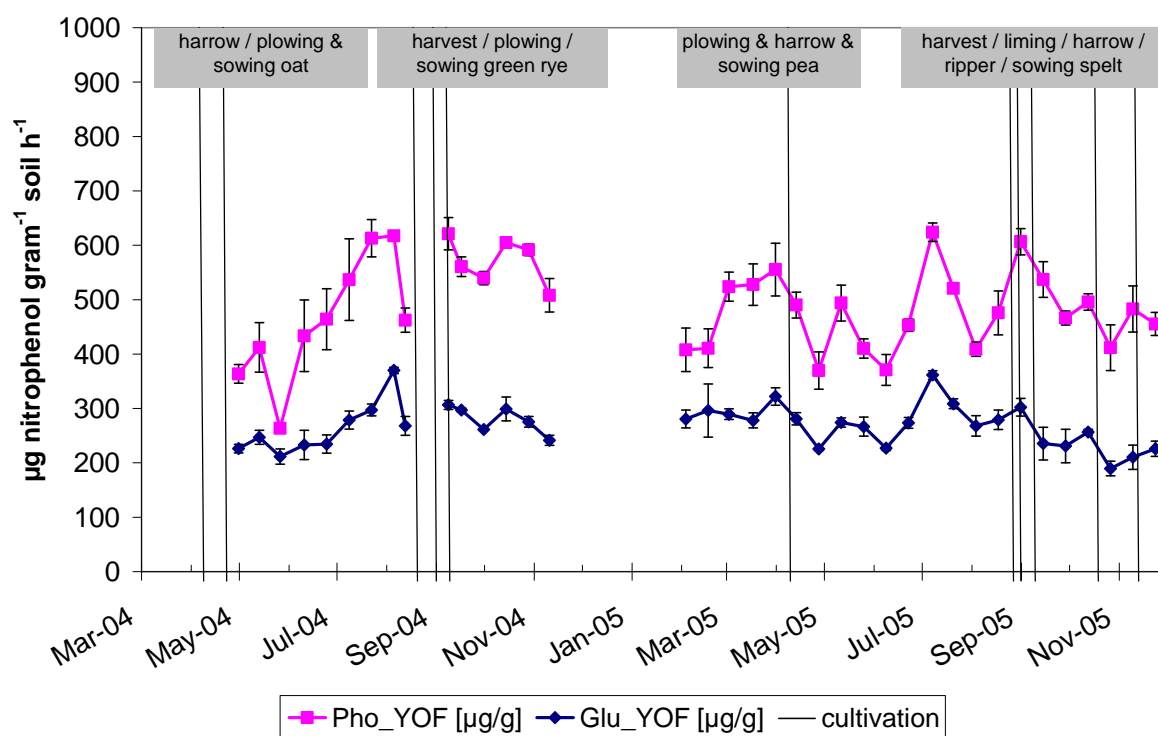
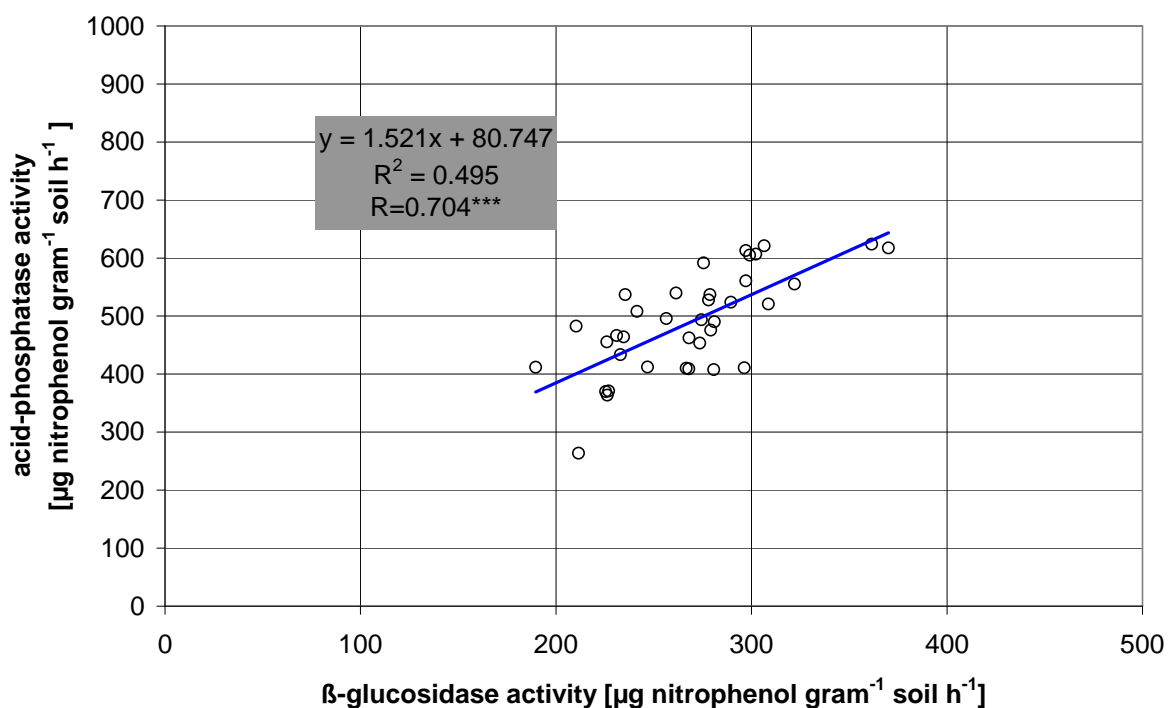


Fig. 24 Enzyme activity of acid-phosphatase (Pho), β -glucosidase (Glu) and cultivation practices at the YOF site in 2004 and 2005

In 2005 the activity of acid-phosphatase was at the first and second sampling time in early February around 408 $\mu\text{g NP/g}^*\text{h}$ ($\pm 1 \mu\text{g NP/g}^*\text{h}$) and rose thereafter until end of March. The β -glucosidase showed at the first sampling 2005 an activity rate of 280 $\mu\text{g NP/g}^*\text{h}$ and showed more or less dynamic changes in the following six weeks. After plowing, harrow disk cultivation, and sowing pea the enzyme activity of acid-phosphatase and β -glucosidase

decreased. In May and mid of summer (07-July) the highest activity values were measured for acid-phosphatase (max. 624 $\mu\text{g NP/g}\cdot\text{h}$) and β -glucosidase (max. 361 $\mu\text{g NP/g}\cdot\text{h}$). Before harvest, both enzyme activities rose and reached after harvest and lime application 606 $\mu\text{g NP/g}\cdot\text{h}$ for acid-phosphatase and 302 $\mu\text{g NP/g}\cdot\text{h}$ for β -glucosidase. After the fall cultivation the enzyme activity of acid-phosphatase and β -glucosidase showed in general a decreasing trend until the last sampling in November 2005 (Fig. 24).

The regression analysis showed a positive significant ($P < 0.001$) correlation between acid-phosphatase and β -glucosidase with a correlation coefficient of $R = 0.704$ and a coefficient of determination of $R^2 = 0.495$ (Fig. 25).

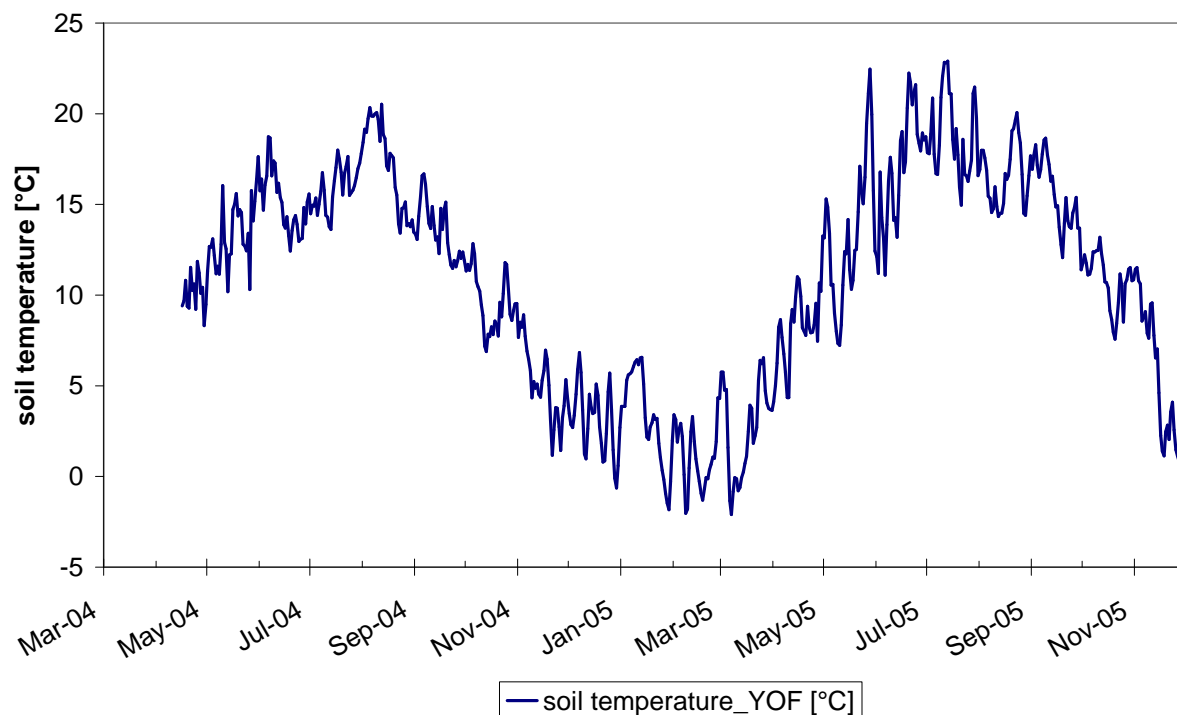


Level of significance: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, n.s. not significant, respectively

Fig. 25 Relationship between acid-phosphatase and β -glucosidase activity at the YOF site in 2004 and 2005

4.2.2.2 Soil temperature

The soil temperature at the YOF site was shown as a seven day moving average 3 cm below the soil surface. The highest soil temperature was measured at 12-August 2004 (20.5 °C) and decreased thereafter stepwise to -2.1 °C in early January. The precipitation in January and February was fallen as snow and covered the soil surface until late February with a 10 to 20 cm thick layer. After the snow thawed the soil temperature showed an increasing trend until mid of July to 22.8 °C and decreased subsequent until the last sampling in November 2005 (Fig. 26).



* seven day moving average

Fig. 26 Soil temperature* 3 cm below the soil surface at the YOF site in 2004 and 2005

4.2.2.3 Carbon

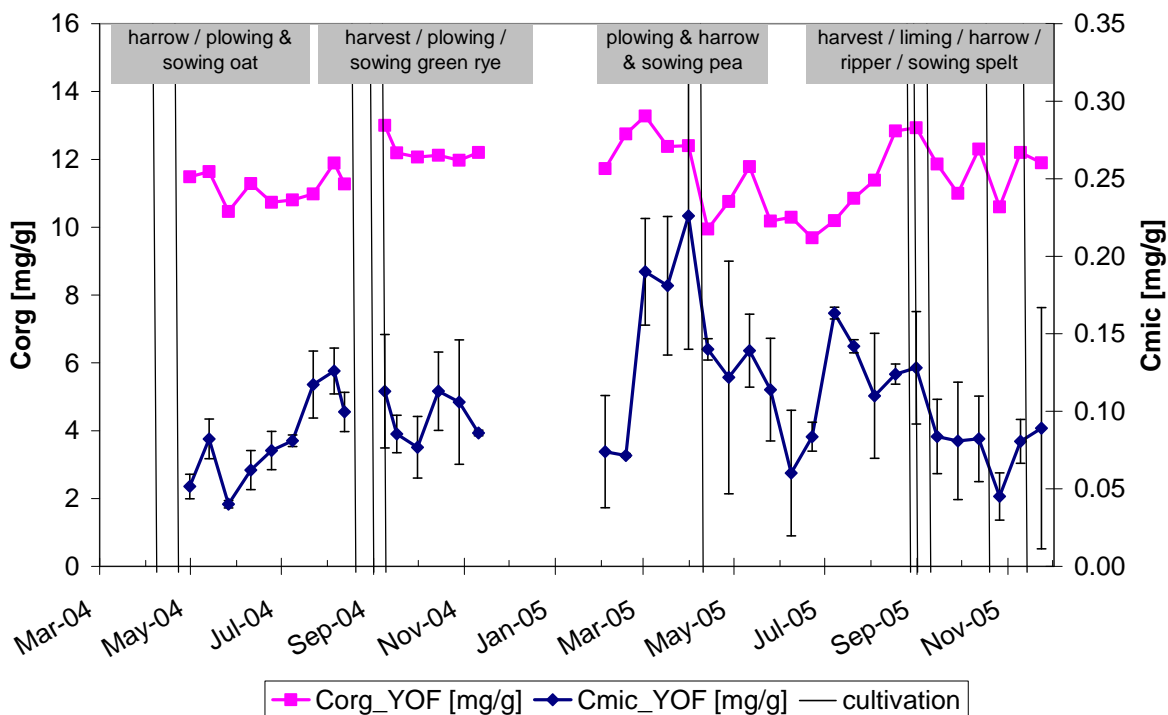
Organic carbon (Corg)

At the beginning of the field experiment at 30-April-2004 the organic carbon (Corg) content was 11.50 mg/g and showed in the following weeks dynamic changes between 10.5 mg/g and 11.9 mg/g. Direct after harvesting, plowing, and sowing green rye the organic carbon content rose to 13.00 mg/g, decreased subsequent to 12.19 mg/g and showed in fall 2004 weak dynamic changes. In the early February 2005 the organic carbon (Corg) content was nearly at the same level compared to the November 2004 data and raised until 02-March-2005 to 13.3 mg/g. After plowing, harrow disk cultivation and sowing the organic carbon content decreased in the following weeks to 9.9 mg/g and showed in fall 2005 dynamic changes between 10.6 mg/g and 11.3 mg/g (Fig. 27).

Microbial carbon (Cmic)

At the first sampling time in 2004 (30-April) the microbial carbon content was 0.052 mg/g and rose (with one exception) until 05-August-2004 to 0.126 mg/g. After harvest, plowing and sowing in fall 2004 the microbial carbon content was 0.113 mg/g (08-September-2004) and decreased subsequent to 0.077 mg/g until 30-September. Thereafter the microbial carbon content rose approximately to the initial content (0.113 mg/g). In the last four weeks of the fall vegetation period the microbial carbon content decreased stepwise to 0.086 mg/g at 10-October-2004.

In 2005 the sampling started again at 03-February-2005 approximately at the same level as at the last sampling mid of November 2004 and showed an increasing trend until 31-March (0.23 mg/g). After plowing, harrow disk cultivation and sowing pea the microbial carbon content decreased stepwise to 0.06 mg/g at 8-June. In the following weeks an increasing tendency was found with a maximum level of 0.16 mg/g at 07-July-2005. Subsequent to soil cultivation practices the microbial carbon content decreased to 0.11 mg/g at 03-August and changed thereafter in a small scale until 31-August. The microbial carbon content in general decreased after fall cultivation to 0.05 mg/g at 26-October and increased in a small scale in September-2005 (Fig. 27).



Error bars indicate the standard deviation between 3 replications (not visible for Corg)

Fig. 27 Organic carbon (Corg) content, microbial carbon (Cmic) content as well as cultivation practices at the YOF site in 2004 and 2005

Cmic/Corg ratio

The Cmic/Corg ratio at the beginning of the field experiment in spring 2004 was 0.4 % and showed an increasing trend to 1.1 % until 22-July-2004. After harvest, plowing and seeding the Cmic/Corg ratio showed in fall 2004 dynamic changes between 0.006 and 0.009. After the winter period the Cmic/Corg ratio showed more or less the same value in February-2005 as compared to the last sampling in November 2004. Thereafter the Cmic/Corg ratio increased in general to 2.0 % until end of March, decreased until 08-June-2005 and increased subsequently until 07-July. After the summer period the Cmic/Corg ratio decreased stepwise until 26-October and rose subsequently in the following four weeks (Fig. 28).

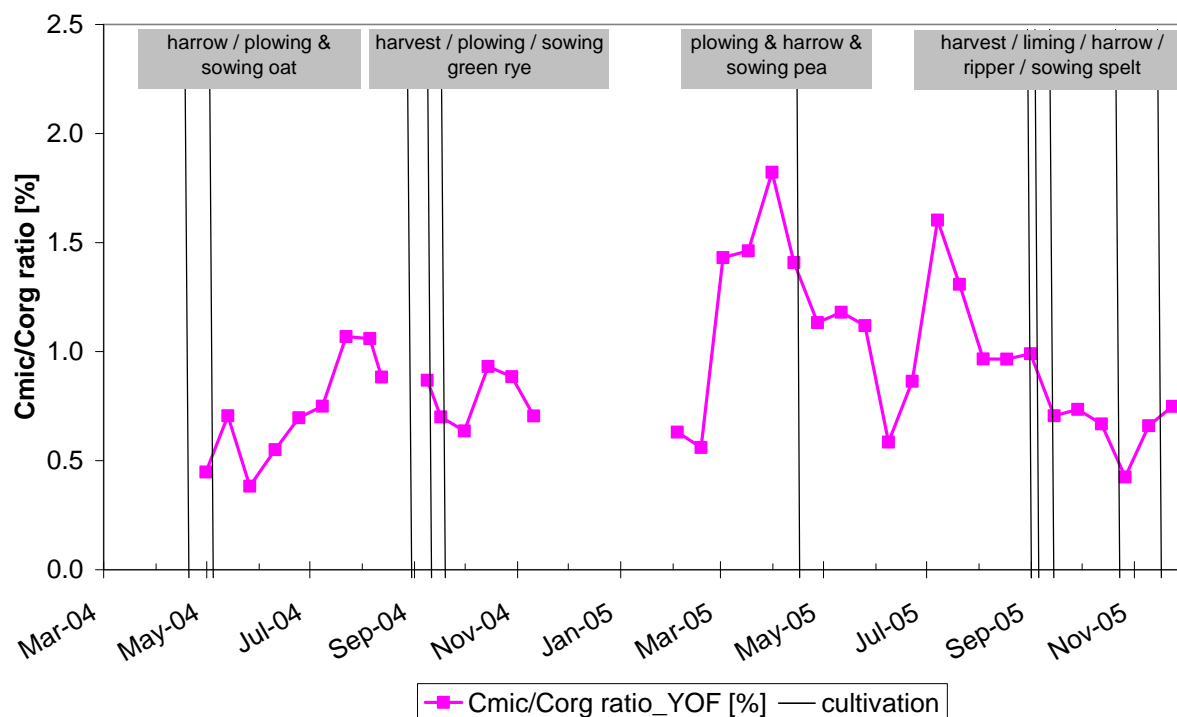
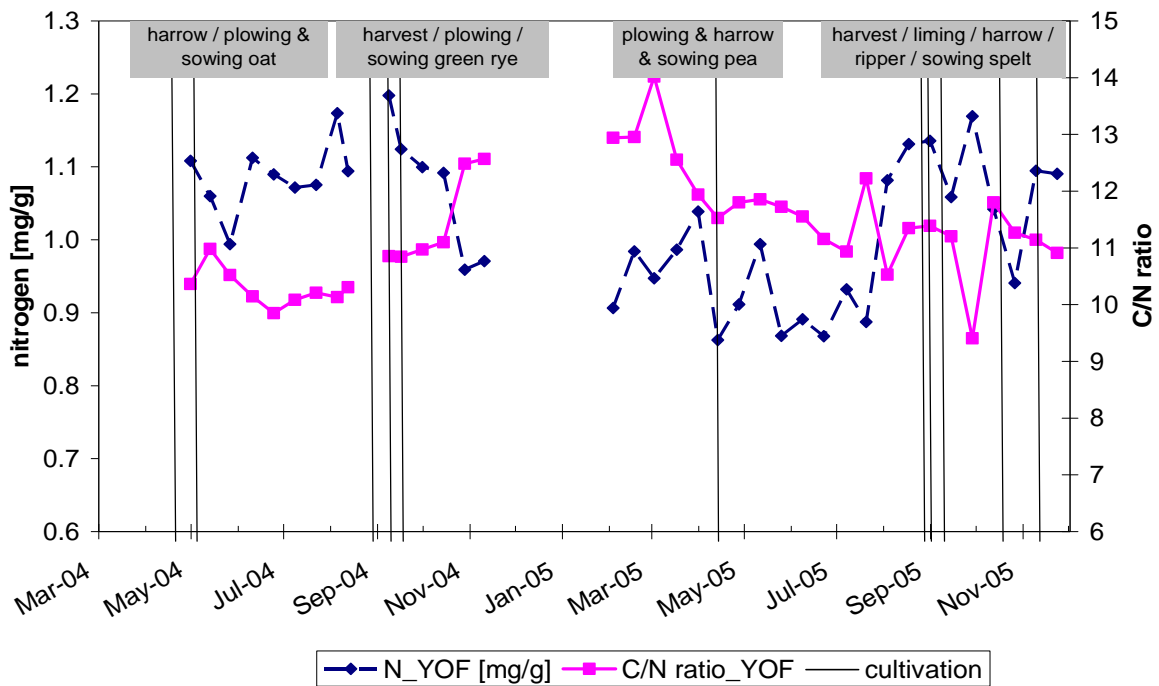


Fig. 28 Cmic/Corg ratio as well as cultivation practices at the YOF site in 2004 and 2005

4.2.2.4 Nitrogen and C/N ratio

At the first sampling in 2004 the nitrogen content was 1.18 mg/g and ranged until harvest in fall 2004 between 0.99 mg/g and 1.17 mg/g. After the cultivation practices such as plowing and sowing the nitrogen content increased to 1.2 mg/g and decreased thereafter until 10-November-2004. At the first sampling in 2005 the nitrogen content was more or less comparable to the value reached at the last sampling in 2004. In spring 2005 the nitrogen showed an increasing trend until end of March and decreased after subsequent cultivation practices. In the summer period 2005 the nitrogen content was between 0.86 and 1.13 mg/g and showed a decreasing tendency in fall and rose thereafter again (Fig. 29).

The C/N ratio ranged between 9.85 and 10.98 in spring and summer 2004 and rose after fall cultivation to 12.57. At the first sampling February-2005 the C/N ratio showed more or less the same value as at the last sampling in 2004 and showed a decreasing trend until late September 2004 with a C/N ratio of 9.41. Thereafter the C/N ratio increased and decreased in the following weeks stepwise (Fig. 29).



Error bars indicate the standard deviation between 3 replications (not visible at this scale)

Fig. 29 Nitrogen content, C/N ratio and cultivation practices at the YOF site in 2004 and 2005

4.2.2.5 pH-value

In spring and summer 2004 the pH-value ranged between pH 6.1 and pH 6.5. After fall cultivation the pH value was 5.9, increased thereafter and showed until the last sampling in 2004 nearly constant conditions. In early 2005 as well as in springtime the pH-value showed dynamic changes between 6.0 and 6.2 and decreased at 08-June-2005 to pH 5.3. Thereafter the pH-value showed an increasing trend to pH 7.4 (with exceptions at 3-August, 14-September and 26-October-2005) at the last sampling in November 2005 (Fig. 30).

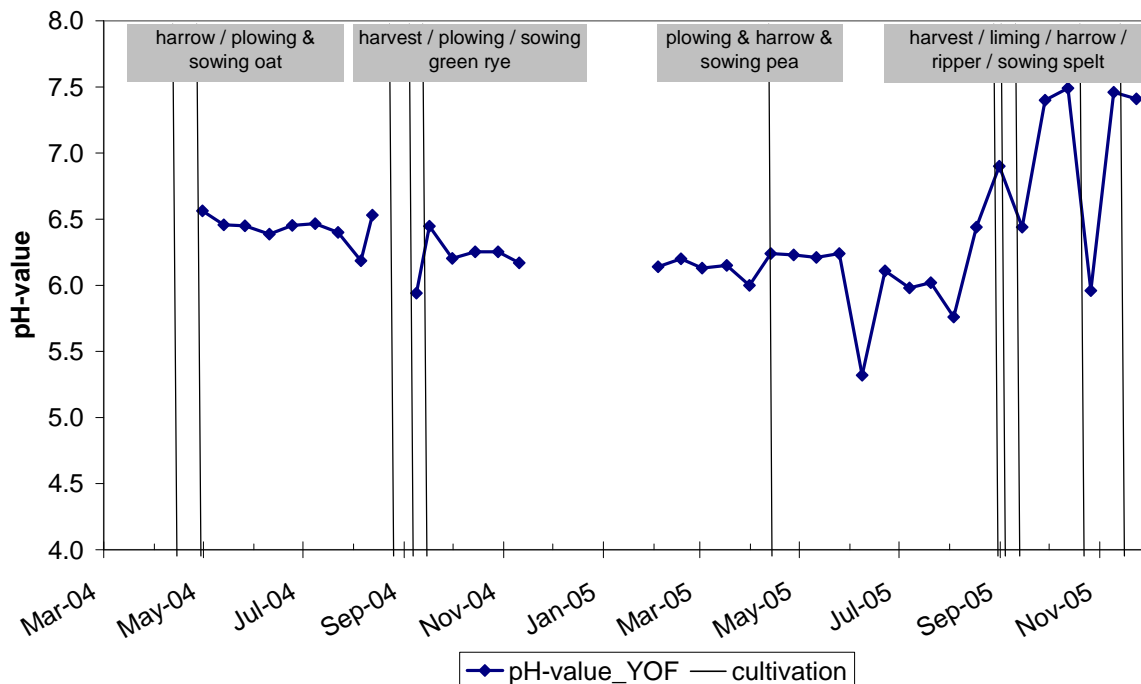


Fig. 30 pH-value and cultivation practices at the YOF site in 2004 and 2005

4.2.2.6 Soil moisture content

In the year 2004 the water content at the OOF site ranged between dry conditions (e.g. 2.9 %) in spring and at the end of summer 2004 and moist conditions in June (e.g. 15.8 %) and fall (e.g. 17.6 %). In 2005 the soil moisture was high in early February and showed a decreasing tendency until June. In July the moisture content increased to 15.0 % and showed alternating dry and moist condition in fall 2005 with an increasing trend until the last sampling in 2005. The moisture dynamics in 2005 showed a broad-spectrum between 3.0 % and 24.0 % moisture content (Fig. 31).

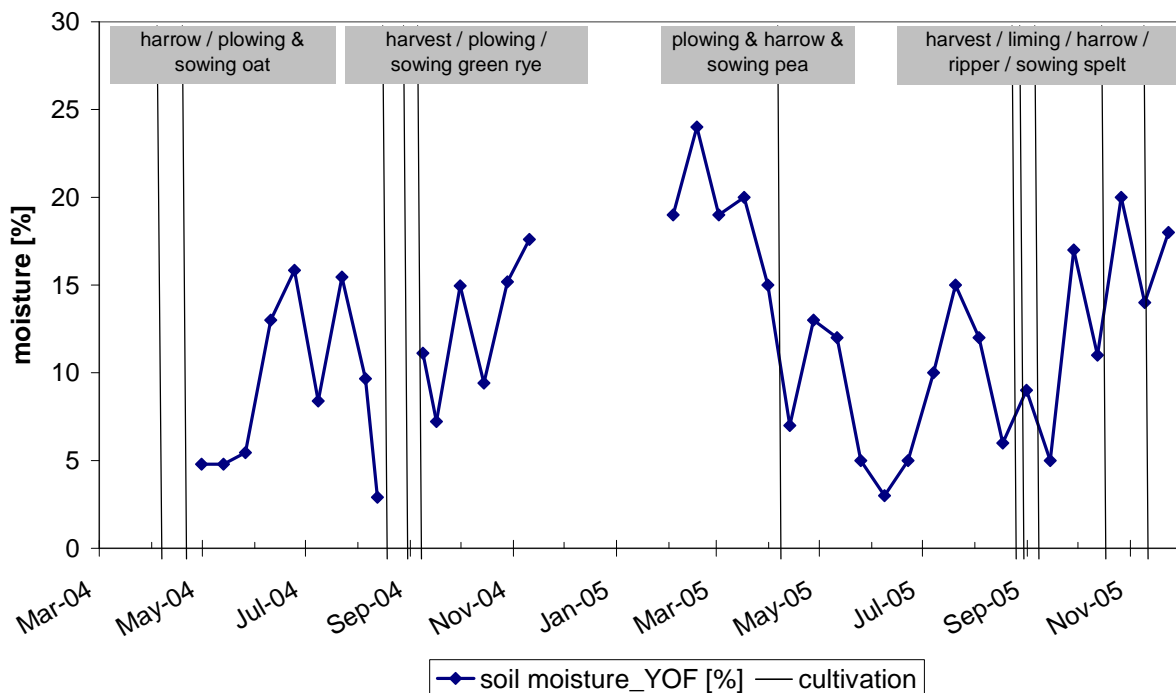


Fig. 31 Soil moisture content in the upper 3 cm of the YOF soil samples as well as cultivation practices in 2004 and 2005

4.2.2.7 Soil surface roughness

The image analysis at the YOF site started as well as at the OOF site according to the soil sampling intervals for the biotic and abiotic analysis after sowing and rolling at 30-April-2004. The initial aggregation ratio was of 49.8 % and decreased to 44.1 % until 10-June-2004. The additional precipitation of 56.4 mm (with 42.5 mm precipitation between 17 and 24-June and a maximum intensity of 4.5 mm/h) resulted in an aggregation ratio of 31.3 % at 24-June. Thereafter the aggregation ratio declined to 20 % at 22-July (total precipitation: 203.7 mm) and to 4.5 % (05-August) after a total precipitation sum of 228.8 mm. The visual assessment showed that only weak crusting signs were visible after 39.9 mm precipitation and clearly visible after 96.3 mm precipitation and observable until the last image analysis. The image analysis stopped at 05-August-2004 according to the following harvest and cultivation practices (Fig. 32).

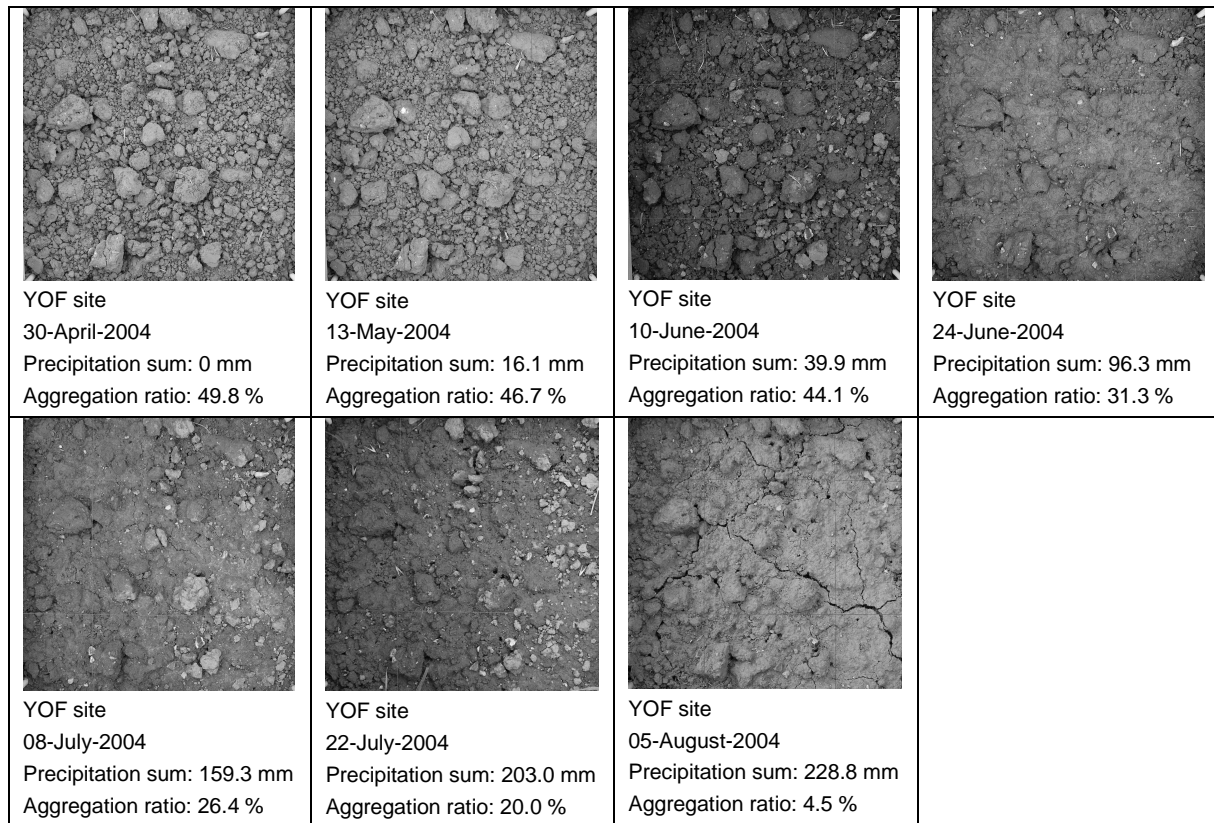


Fig. 32 Image sequence of the inner core unit at the YOF site, beginning at 30-April-2004 until 05-August-2004

The aggregation ratio at the YOF soil surface in combination with the precipitation sum is shown in Fig. 33.

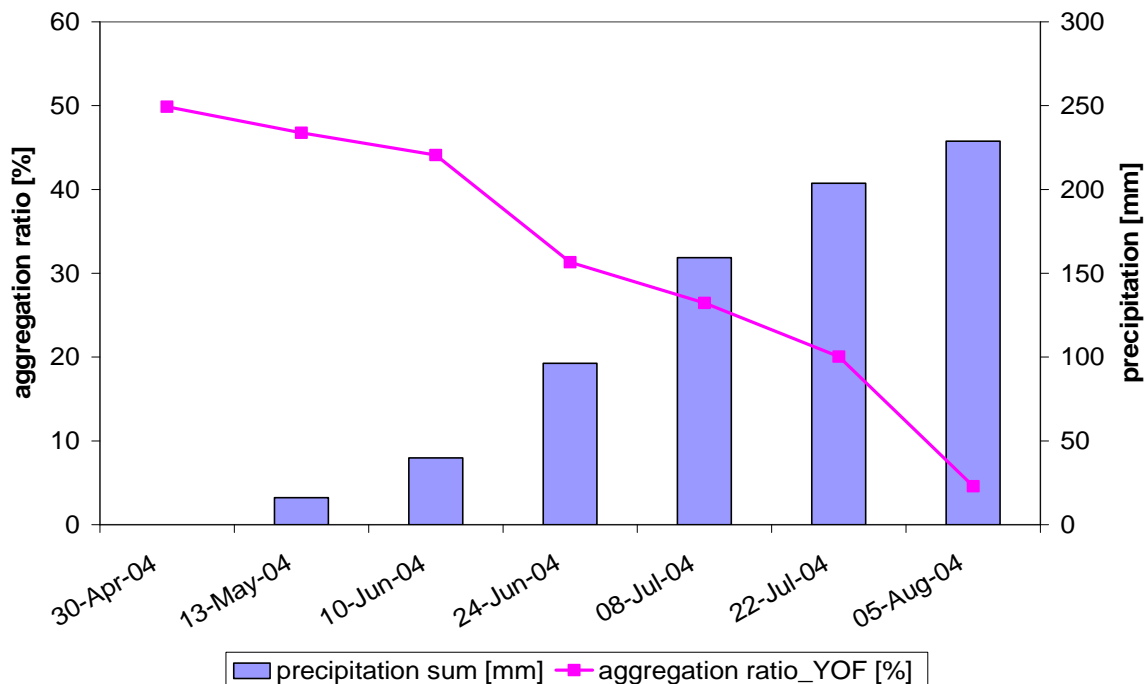


Fig. 33 Precipitation sum and aggregation ratio in 2004 at the YOF site, beginning at 30-April-2004 until 05-August-2004

In 2005 the image analysis started as well as the other sites (OOF, CF) at 13-April after sowing (without rolling) with an initial aggregation ratio of 39.5 %. After 57.5 mm precipitation (maximum intensity: 5.8 mm/h) the aggregation ratio decreased to 31.5 % at 11-May and to 29.0 % at 25-May-2005 (total precipitation: 68.1 mm; maximum precipitation intensity: 2.5 mm/h). After a total precipitation sum of 91.5 mm and a maximum intensity of 2.6 mm per hour, the aggregation ratio declined to 23.0 % at 08-June. Thereafter the aggregation ratio at 07-July was nearly unaffected of 37.8 mm additional precipitation (maximum intensity: 4.7 mm/h) and decreased at 20-July to 22.0 % after 37.8 mm additional precipitation (total precipitation: 145.6 mm; maximum precipitation intensity: 12.7 mm/h). At 03-August the aggregation ratio was 20.3 % (precipitation sum: 225.6 mm; maximum precipitation intensity: 5.1 mm/h) and showed after 259.7 mm total precipitation, with a maximum intensity of 10.6 mm/h, a final aggregation ratio of 19.5 % at 17-August-2005 (Fig. 34). The visual assessment of the images revealed that after 68.1 mm precipitation the soil surface showed first crusting signs which were more pronounced until the last image was taken. The image analysis at the YOF site stopped at 17-August-2005 because of the following harvest at 18-August-2005.

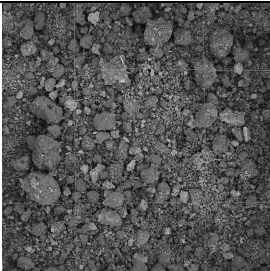
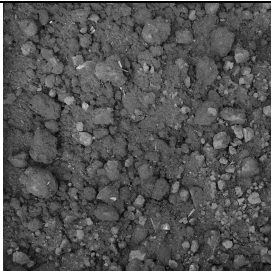
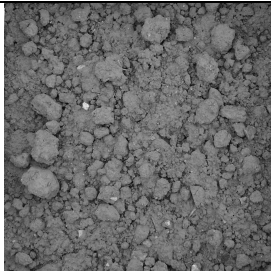
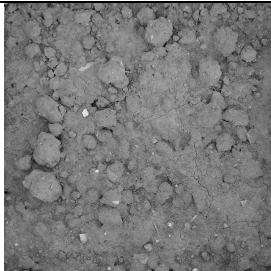
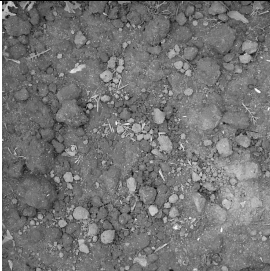
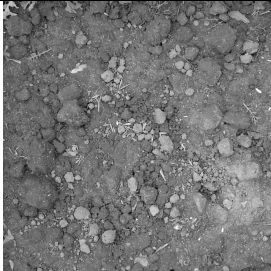
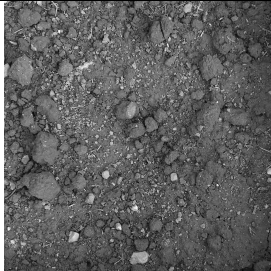
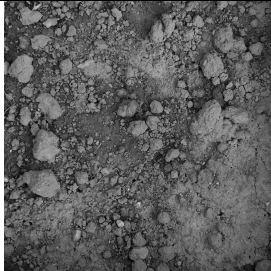
			
YOF site 13-April-2005 Precipitation sum: 0 mm Aggregation ratio: 39.5 %	YOF site 11-May-2005 Precipitation sum: 57.5 mm Aggregation ratio: 31.5 %	YOF site 25-May-2005 Precipitation sum: 68.1 mm Aggregation ratio: 29.0 %	YOF site 08-June-2005 Precipitation sum: 91.5 mm Aggregation ratio: 23.0 %
			
YOF site 07-July-2005 Precipitation sum: 129.3 mm Aggregation ratio: 22.2 %	YOF site 20-July-2005 Precipitation sum: 145.6 mm Aggregation ratio: 22.0 %	YOF site 03-August-2005 Precipitation sum: 225.6 mm Aggregation ratio: 20.3 %	YOF site 17-August-2005 Precipitation sum: 259.7 mm Aggregation ratio: 19.5 %

Fig. 34 Image sequence of the inner core unit at the YOF site, beginning at 13-April-2005 until 17-August-2005

Additional to the image sequence at the YOF site (Fig. 34) the aggregation ratio in combination with the precipitation sum is shown in Fig. 35 to see the dynamic processes at the soil surface in 2005.

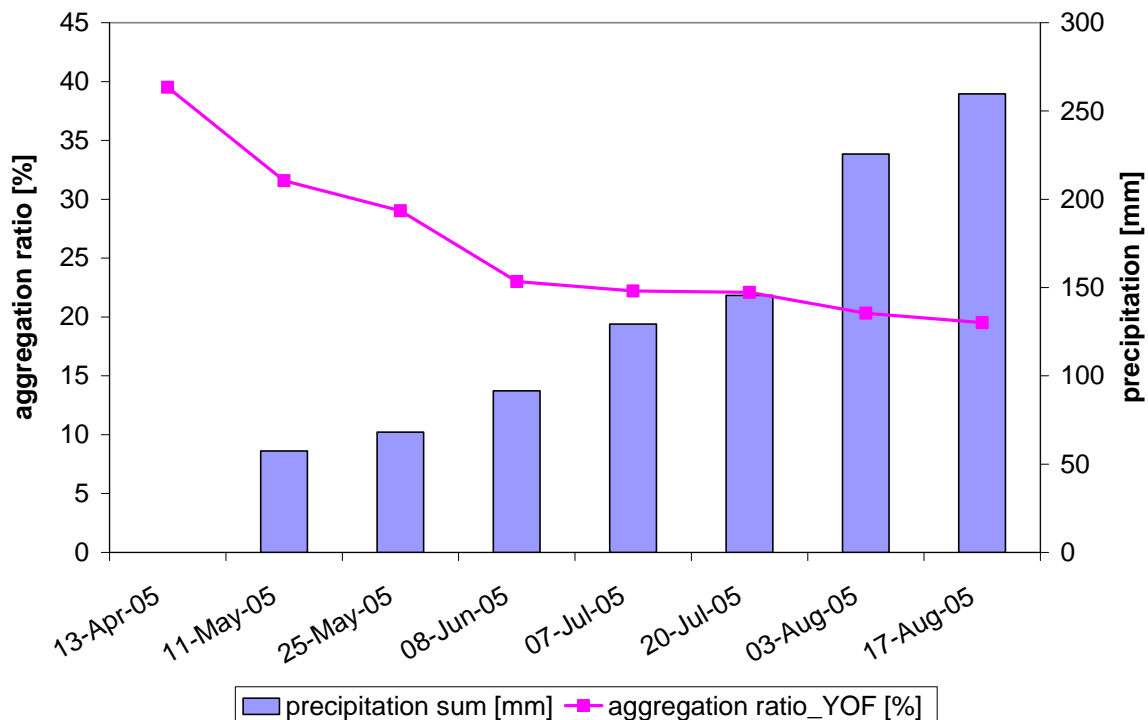


Fig. 35 Aggregation ratio and precipitation sum in 2005 at the YOF site, beginning at 13-April-2005 until 17-August-2005

4.2.2.8 Correlation statistics

The statistical analysis showed that in general the acid-phosphatase and β -glucosidase activity correlated negatively and significantly to the aggregation ratio (with an exception for the year 2005) and significant positive to the Corg content, Cmic content and the Cmic/Corg ratio (with some exception for β -glucosidase and acid-phosphatase correlated with Corg). The other factors such as nitrogen content, C/N ratio, pH-value, moisture content, soil temperature (as seven day moving average) and the precipitation sum showed in common (with only a few exceptions) no significant correlations to the enzyme activities of acid-phosphatase and β -glucosidase (Table 7).

Furthermore the correlation coefficients between the aggregation ratio at the soil surface and biotic and abiotic factors were shown in Table 8. The aggregation ratio showed negative correlation coefficients to the enzyme activities (with exceptions in 2005, as described above), to the soil temperature and to the total precipitation sum. In addition positive significant correlations were found to the pH-value as well to the soil moisture content in 2004. Negative as well as positive significant correlations could be found between the Corg, Cmic, Cmic/Corg ratio, nitrogen content, C/N ratio and the soil surface aggregation.

Table 7 Correlation coefficients (R)^a between enzyme activities^b and biotic and abiotic parameters^c at the YOF site for 2004, 2005 and 2004/2005

variable	site	acid-phosphatase			β-glucosidase		
		2004	2005	2004/2005	2004	2005	2004/2005
aggregation ratio	YOF	-0.950***	0.093 ^{n.s.}	-0.569**	-0.922***	-0.048 ^{n.s.}	-0.669***
Corg	YOF	0.586***	0.311*	0.378*	0.464**	0.127 ^{n.s.}	0.225 ^{n.s.}
Cmic	YOF	0.890***	0.605**	0.529***	0.866***	0.680***	0.653***
Cmic/Corg ratio	YOF	0.846***	0.568***	0.481**	0.834***	0.704***	0.650***
nitrogen	YOF	0.329*	0.283 ^{n.s.}	0.322*	0.529**	0.161 ^{n.s.}	0.063 ^{n.s.}
C/N ratio	YOF	0.211 ^{n.s.}	0.005 ^{n.s.}	0.011 ^{n.s.}	0.065 ^{n.s.}	0.320 ^{n.s.}	0.145 ^{n.s.}
pH-value	YOF	-0.613***	0.203 ^{n.s.}	0.009 ^{n.s.}	-0.480**	-0.302 ^{n.s.}	-0.297 ^{n.s.}
moisture	YOF	0.454**	0.066 ^{n.s.}	0.117 ^{n.s.}	0.044 ^{n.s.}	0.022 ^{n.s.}	0.005 ^{n.s.}
temp	YOF	0.330*	0.205 ^{n.s.}	0.264 ^{n.s.}	0.552***	0.038 ^{n.s.}	0.184 ^{n.s.}
precipitation sum	YOF	0.718***	0.112 ^{n.s.}	0.025 ^{n.s.}	0.436**	-0.494 ^{n.s.}	0.073 ^{n.s.}

^a Level of significance: * P < 0.05, ** P < 0.01, *** P < 0.001, n.s. not significant

^b Acid-phosphatase, β-glucosidase

^c Aggregation ratio, organic carbon content (Corg), microbial carbon content (Cmic), Cmic/Corg ratio, nitrogen content, C/N ratio, pH-value, soil moisture content (moisture), soil temperature as seven day moving average (temp) and precipitation sum

Table 8 Correlation coefficients (R)^a between the aggregation ratio and biotic and abiotic parameters^b at the YOF site for 2004, 2005 and 2004/2005

variable	site	Aggregation ratio		
		2004	2005	2004/2005
Pho	YOF	-0.950***	0.093 ^{n.s.}	-0.569**
Glu	YOF	-0.922***	-0.048 ^{n.s.}	-0.669***
Corg	YOF	-0.026 ^{n.s.}	-0.390*	0.098 ^{n.s.}
Cmic	YOF	-0.891***	0.308*	-0.475**
Cmic/Corg	YOF	-0.895***	0.418**	-0.384*
nitrogen	YOF	-0.493**	-0.505***	0.056 ^{n.s.}
C/N ratio	YOF	0.190 ^{n.s.}	0.360*	-0.128 ^{n.s.}
pH-value	YOF	0.793***	0.428*	0.459**
moisture	YOF	-0.404**	-0.101 ^{n.s.}	-0.218 ^{n.s.}
temp	YOF	-0.868***	-0.842***	-0.648***
precipitation sum	YOF	-0.974***	-0.847***	-0.827***

^a Level of significance: * P < 0.05, ** P < 0.01, *** P < 0.001, n.s. not significant

^b Acid-phosphatase (Pho), β-glucosidase (Glu), organic carbon content (Corg), microbial carbon content (Cmic), Cmic/Corg ratio, nitrogen content, C/N ratio, pH-value, soil moisture content (moisture), soil temperature as seven day moving average (temp) and precipitation sum

4.2.3 Conventional Farming site

4.2.3.1 Enzyme activity

In Fig. 36 the enzyme activities of acid-phosphatase and β -glucosidase at the Conventional Farming (CF) site were shown. The activity values ranged in the whole experimental period between 230 $\mu\text{g NP/g}^*\text{h}$ and 767 $\mu\text{g NP/g}^*\text{h}$ with a statistical mean of 469 $\mu\text{g NP/g}^*\text{h}$ for acid-phosphatase and between 145 $\mu\text{g NP/g}^*\text{h}$ and 345 $\mu\text{g NP/g}^*\text{h}$ with a statistical mean of 202 $\mu\text{g NP/g}^*\text{h}$ for β -glucosidase.

In spring 2004 the cultivation practices included liquid manure and urea application as well as plowing and sowing corn. After the seedbed was fully prepared the soil sampling started at 30-April-2004 with an activity rate of 456 $\mu\text{g NP/g}^*\text{h}$ for acid-phosphatase. After herbicide application (Gardo Gold, Callisto), the activity of acid-phosphatase decreased stepwise to 230 $\mu\text{g NP/g}^*\text{h}$ at 26-May and increased in the following weeks stepwise to 482 $\mu\text{g NP/g}^*\text{h}$ and showed subsequently more or less the same activity level until harvest (with an exception at mid of September). After harvest at 11-October the activity of acid-phosphatase raised and decreased again at the last sampling time in 2004 (10-November).

The β -glucosidase activity at the first sampling in 2004 was 190 $\mu\text{g NP/g}^*\text{h}$ and decreased in the subsequent weeks. Thereafter the glucosidase activity showed an increasing tendency with lower levels in September. After harvest the activity of β -glucosidase increased to 238 $\mu\text{g NP/g}^*\text{h}$ at 28-October and decreased at the last sampling time at 10-November-2004 to 211 $\mu\text{g NP/g}^*\text{h}$ (Fig. 36).

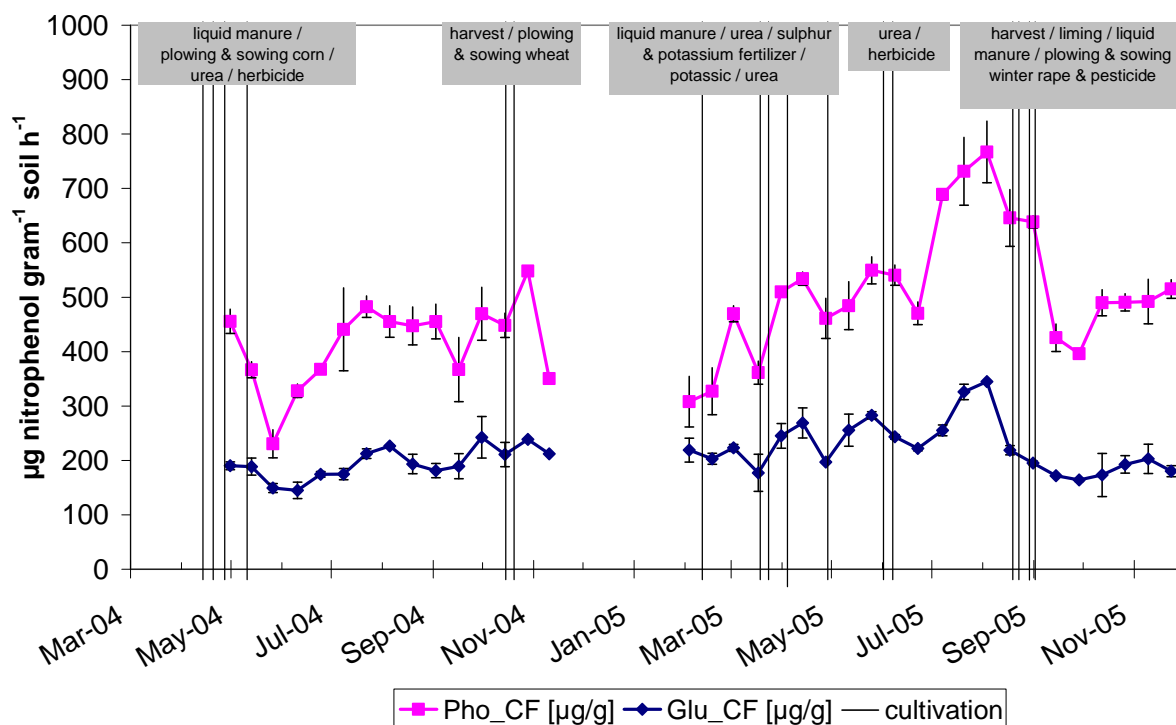
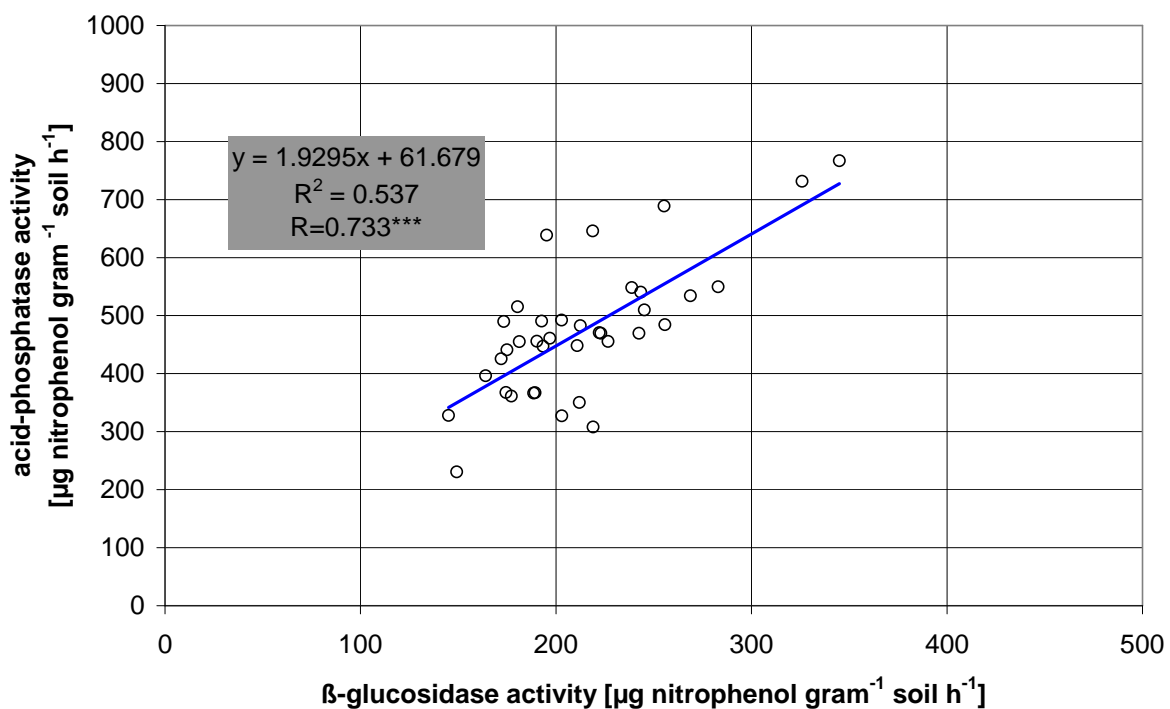


Fig. 36 Enzyme activity of acid-phosphatase (Pho), β -glucosidase (Glu) and cultivation practices at the CF site in 2004 and 2005

The sampling period 2005 started for the CF site at the same date as at the organic farming sites. At the first sampling on 03-February-2005 the enzyme activity of acid-phosphatase and β -glucosidase showed more or less the same activity values as at the last sampling in 2004. After liquid manure application the enzyme activities increased till 02-March to 469 $\mu\text{g NP/g}\cdot\text{h}$ and declined subsequently. After urea, sulfur and potassium fertilizer as well as an additional potassic fertilizer the activity increased to 534 $\mu\text{g NP/g}\cdot\text{h}$ for acid-phosphatase and to 268 $\mu\text{g NP/g}\cdot\text{h}$ for β -glucosidase at 13-April. Thereafter the enzyme activities decreased and increased after urea application at 26-April-2005. Subsequent to an additional urea and herbicide (input, U46M, impulse) application the enzyme activities decreased till 22-June and increased in the following six weeks to 767 $\mu\text{g NP/g}\cdot\text{h}$ for acid-phosphatase and 345 $\mu\text{g NP/g}\cdot\text{h}$ for β -glucosidase. After harvest, lime and liquid manure application, plowing, sowing rape and an additional pesticide application the activity decreased step by step in the following weeks but increased thereafter until the last sampling in 2005 to 515 $\mu\text{g NP/g}\cdot\text{h}$ for acid-phosphatase and 180 $\mu\text{g NP/g}\cdot\text{h}$ for β -glucosidase (Fig. 36).

The regression analysis showed between acid-phosphatase and β -glucosidase a high positive significant correlation ($P < 0.001$) with a correlation coefficient of $R = 0.733$ and a coefficient of determination of $R^2 = 0.537$ (Fig. 37).

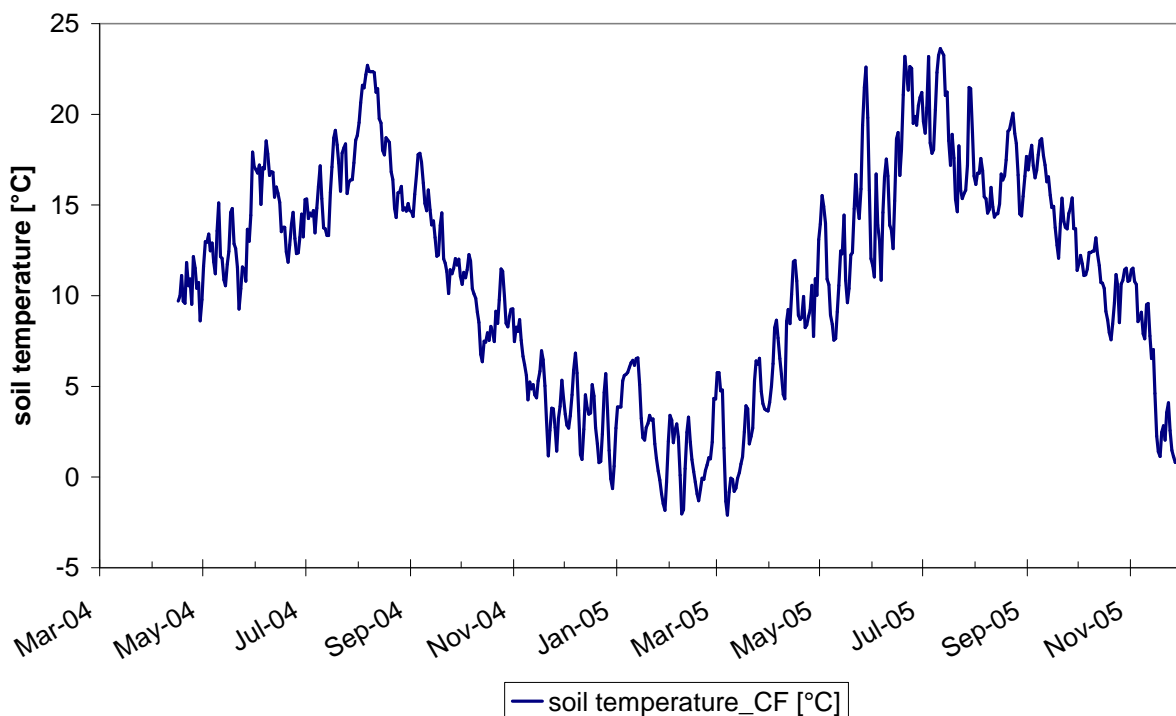


Level of significance: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, n.s. not significant, respectively

Fig. 37 Relationship between acid-phosphatase and β -glucosidase activity at the CF site in 2004 and 2005

4.2.3.2 Soil temperature

The soil temperature at the CF site was shown as a seven day moving average in Fig. 38. In spring 2004 the soil temperature 3 cm below the soil surface ranged between 8.6 °C and 15.1 °C and increased in summer 2004 to approximately 22 °C (8-August-2004). Thereafter the soil temperature decreased stepwise to -2.1 °C in early January. In late January the precipitation was fallen as snow and covered the soil surface with a 10 to 20 cm thick layer until late February. After the snow thawed the soil temperature rose in general (with dynamic changes) to 23.4 °C at mid of July-2005 and showed thereafter a decreasing trend until winter.



* seven day moving average

Fig. 38 Soil temperature* 3 cm below the soil surface at the CF site in 2004 and 2005

4.2.3.3 Carbon

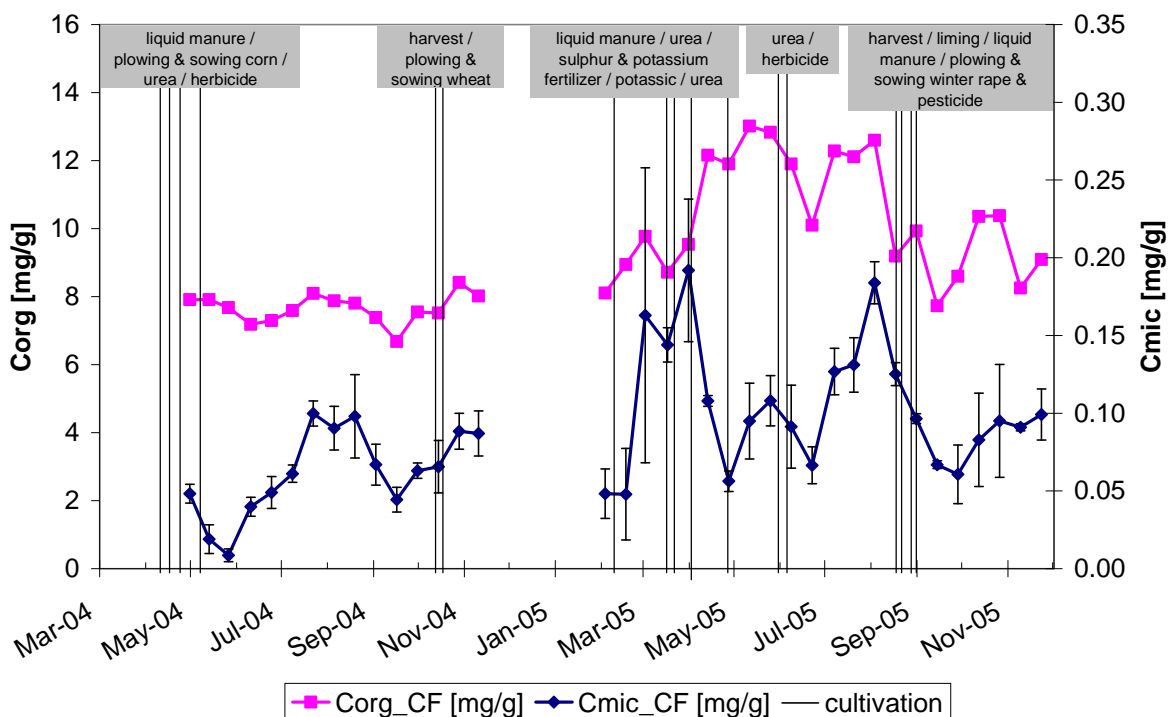
Organic carbon (Corg)

The organic carbon content at 30-April-2004 was 9.71 mg/g and showed no change one day after herbicide application, but decreased in the next four weeks to 7.20 mg/g. In the following six weeks the organic carbon content increased stepwise and reached 8.10 mg/g at 22-July-2004. Thereafter the organic carbon decreased again to 6.70 mg/g at 16-September and rose to 7.50 mg/g before harvest. After harvest the organic carbon content increased to 8.40 mg/g at 28-October and fall down to 8.00 mg/g at the last sampling time at 10-November-2004.

At the first sampling in 2005 the organic carbon content was comparable to the content reached at the last sampling in 2004 and showed an increasing trend after liquid manure application and the following spring cultivation until mid of May-2005. After urea and herbicide application the organic carbon content decreased and rose subsequent to 12.6 mg/g at 03-August and declined at the following sampling to 9.2 mg/g at 17-August. After harvest, lime and liquid manure application the organic carbon content increased in a small scale and decreased after plowing, sowing rape and pesticide application to 7.7 mg/g. Subsequent the organic carbon content increased to 10.3 mg/g, decreased thereafter to 8.2 mg/g and increased to 9.1 mg/g at the end of the year 2005 (Fig. 39).

Microbial carbon (Cmic)

The microbial carbon content was at the first sampling in 2004 (30-April) 0.048 mg/g and decreased after herbicide application in the following four weeks to 0.009 mg/g. In the next eight weeks (four sampling times) the microbial carbon content increased stepwise to 0.100 mg/g at 22-July. Subsequent the microbial carbon content was nearly stable and decreased to 0.044 mg/g at 16-September. Before harvest 2004 the content increased to 0.066 mg/g and rose to 0.088 mg/g after harvest and did not changed until the last sampling time two weeks later (Fig. 39).



Error bars indicate the standard deviation between 3 replications (not visible for Corg)

Fig. 39 Organic carbon (Corg) content, microbial carbon (Cmic) content as well as cultivation practices at the CF site in 2004 and 2005

After winter time the microbial carbon content was 0.05 mg/g in February-2005 and showed after liquid manure and fertilizer application an increasing trend to 0.19 mg/g. In the following weeks the microbial carbon content declined to 0.06 mg/g at 27-April. Subsequent to the potassium fertilization the microbial carbon content increased till 25-May to 0.11 mg/g and declined after urea and herbicide application to 0.07 mg/g at 22-June and rose in the following six weeks again to 0.18 mg/g. After harvest, lime, liquid manure and pesticide application as well as plowing and sowing rape the microbial carbon content declined stepwise to 0.06 mg/g until 28-September and increased till the last sampling (23-November-2005) to 0.10 mg/g (Fig. 39).

Cmic/Corg ratio

At the first sampling in 2004 the Cmic/Corg ratio was 0.6 % and decreased after herbicide application to 0.1 % until 26-May. Thereafter the Cmic/Corg content showed an increasing trend until mid of August and decreased subsequently in the following four weeks to 0.7 %. In the fall period the Cmic/Corg content increased to 1.1 % until the last sampling in October 2004. After the winter period the Cmic/Corg ratio was in early 2005 lower than compared to the last sampling in November 2004 and showed then an increasing tendency until end of March. Thereafter the Cmic/Corg ratio increased until August and decreased after fall cultivation to 0.7 % at end of September. After this decrease the Cmic/Corg content increased again in the following weeks to 1.1 % until 23-November-2005 (Fig. 40).

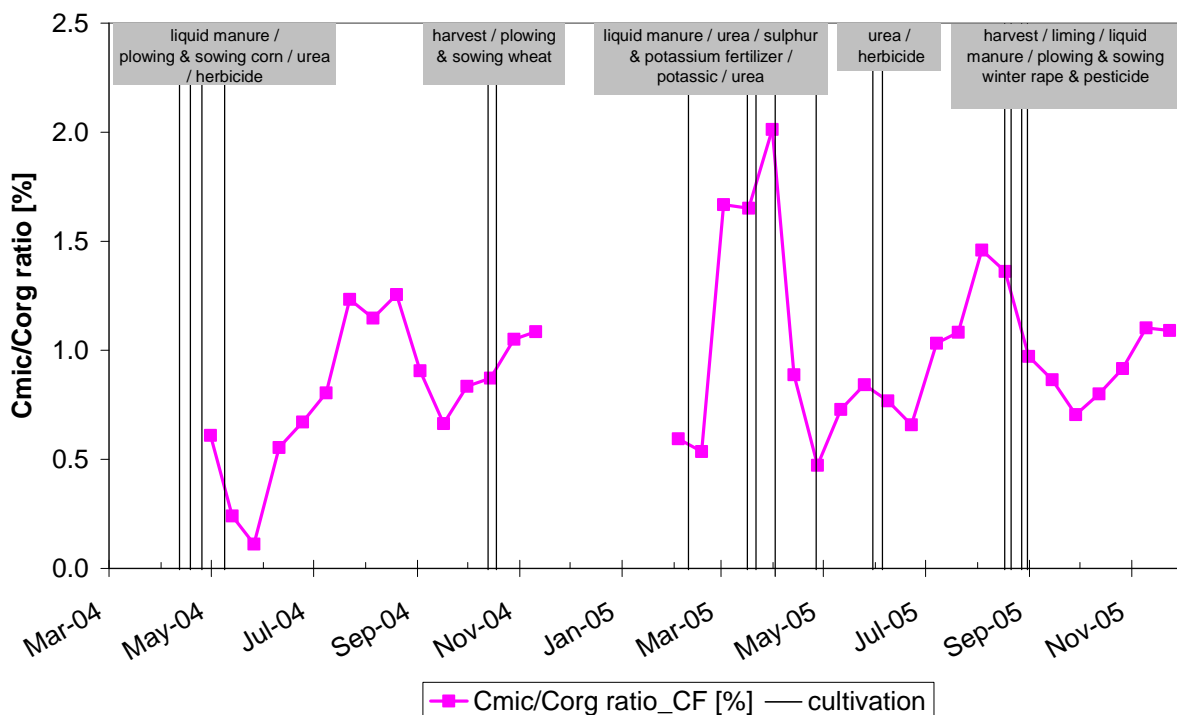
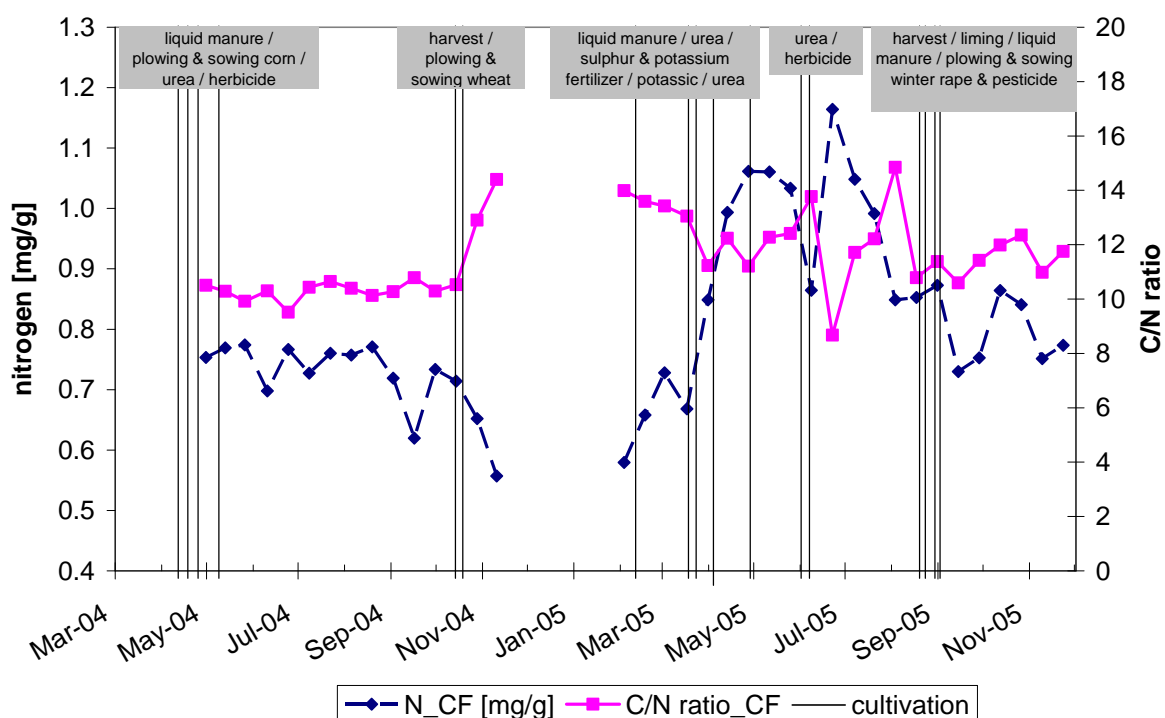


Fig. 40 Cmic/Corg ratio as well as cultivation practices at the CF site in 2004 and 2005

4.2.3.4 Nitrogen and C/N ratio

During spring and summer 2004 the nitrogen content ranged among 0.67 mg/g and 0.77 mg/g and decreased at mid of September to 0.62 mg/g. Thereafter the nitrogen content increased at the following sampling and decreased subsequent until the last sampling in October 2004. At the first sampling in 2005 the nitrogen content was more or less comparable to the value reached at the last sampling in 2004 and showed an increasing trend to 1.14 mg/g until 22-June-2005. Subsequently the nitrogen content decreased until September and showed an increasing trend in October and lower levels in November (Fig. 41).



Error bars indicate the standard deviation between 3 replications (not visible at this scale)

Fig. 41 Nitrogen content, C/N ratio and cultivation practices at the CF site in 2004 and 2005

4.2.3.5 pH-value

The pH-value showed beginning from the first sampling in 2004 (pH=9.2) a stepwise decrease until mid of October (pH=6.2), with one exception in August, and increased after fall cultivation to pH 6.5. In 2005 the pH was in early February 6.9 and decreased until mid of May. Thereafter an increasing trend until the end of September was found (with high pH at mid of June) and decreased stepwise to 6.0 until the last sampling in November-2005 (Fig. 42).

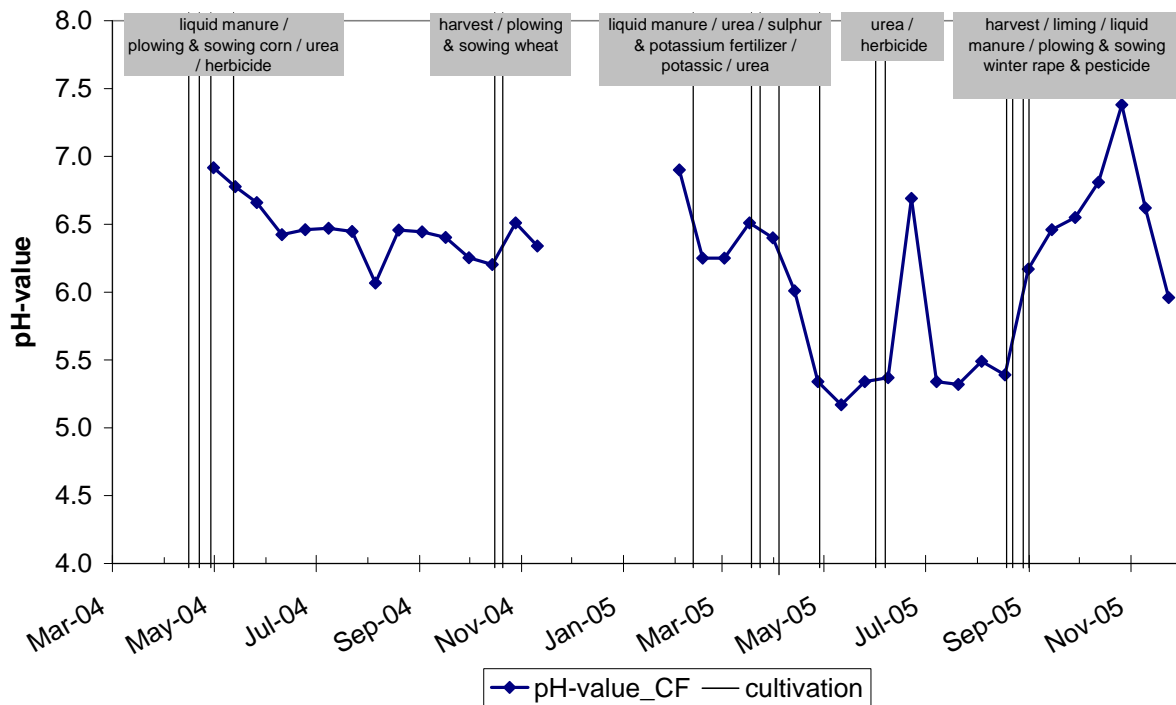


Fig. 42 pH-value and cultivation practices at the CF site in 2004 and 2005

4.2.3.6 Soil moisture content

At the first three sampling times in 2004 dry conditions (water content between 2.7 and 3.0 %) were predominated. Thereafter the water content ranged between dry conditions (e.g. 5.0 %) and moist conditions (e.g. 15.8 %) in June and fall. In 2005 the soil moisture was high in early February (24.0 %) and decreased stepwise to 9.0 % at 13-April.

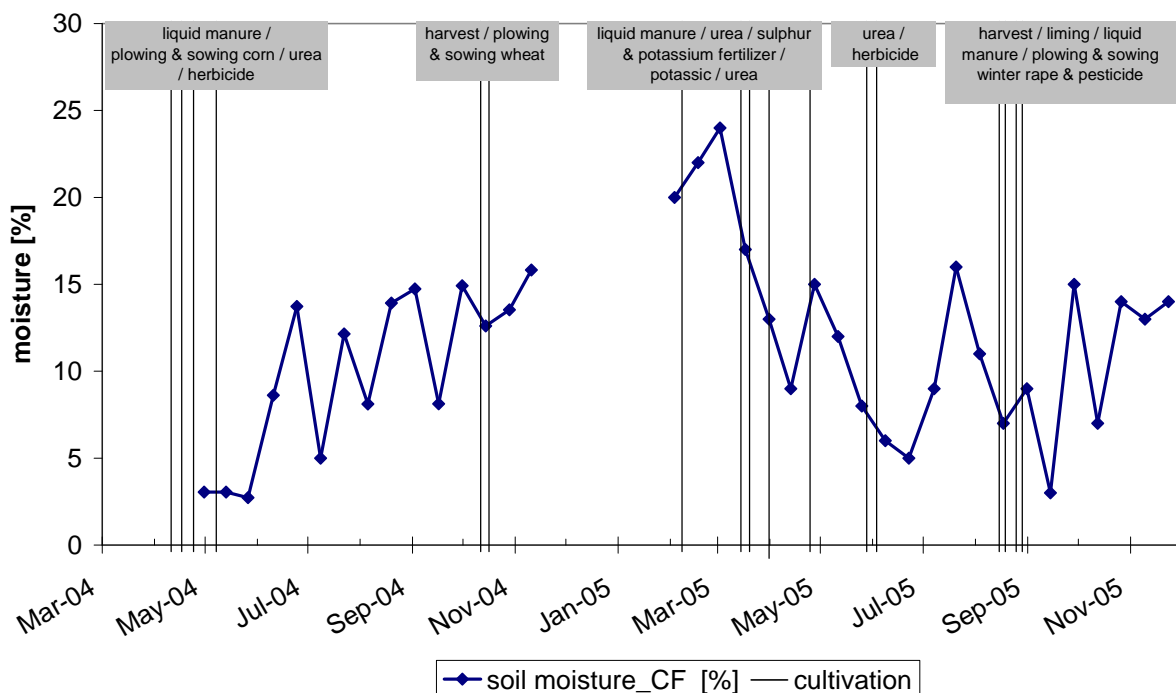


Fig. 43 Soil moisture content at the upper 3 cm of the CF soil samples as well as cultivation practices in 2004 and 2005

Afterwards the soil moisture content increased to 15.0 % at end of April and decreased stepwise until 22-June and increased subsequent in the next two samplings to 16.0 %. At the harvest the soil moisture content was 7.0 % and showed an increasing trend until the last sampling at end of November (Fig. 43).

4.2.3.7 Soil surface roughness

The image analysis started at the CF site after plowing and sowing corn at 30-April-2004 until 14-October-2004. The initial aggregation ratio at the soil surface was 34.9 % and declined after 16 mm precipitation to 31.7 %. After additional 23.8 mm precipitation with an intensive rainfall event at 09-June-2004 (14.1 mm precipitation in 2 hours and a maximum intensity of 4.5 mm/h) the aggregation ratio decreased to 18.9 % at 10-June-2004 (Fig. 44).

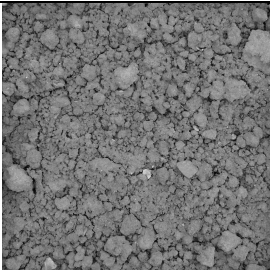
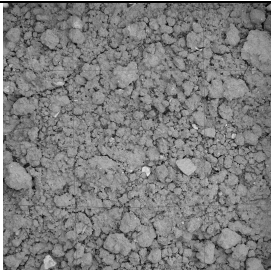

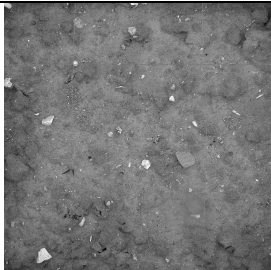
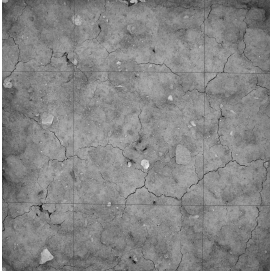



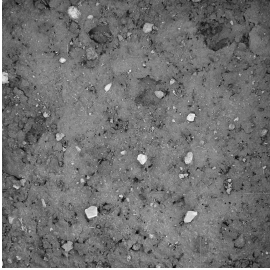
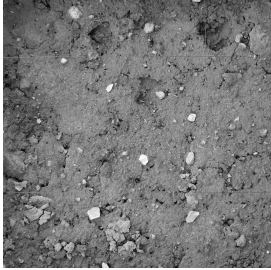
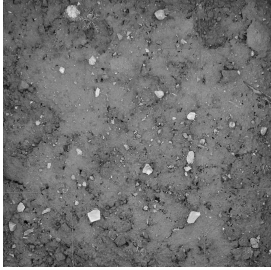

			
CF site 30-April-2004 Precipitation sum: 0 mm Aggregation ratio: 34.9 %	CF site 13-May-2004 Precipitation sum: 16.1 mm Aggregation ratio: 31.7 %	CF site 10-June-2004 Precipitation sum: 39.9 mm Aggregation ratio: 18.9 %	CF site 24-June-2004 Precipitation sum: 96.3 mm Aggregation ratio: 8.3 %
			
CF site 08-July-2004 Precipitation sum: 159.3 mm Aggregation ratio: 2.0 %	CF site 22-July-2004 Precipitation sum: 203.7 mm Aggregation ratio: 0.7 %	CF site 05-August-2004 Precipitation sum: 228.8 mm Aggregation ratio: 0.9 %	CF site 19-August-2004 Precipitation sum: 257.8 mm Aggregation ratio: 0.3 %
			
CF site 02-September-2004 Precipitation sum: 305.2 mm Aggregation ratio: 0.3 %	CF site 16-September-2004 Precipitation sum: 314.2 mm Aggregation ratio: 1.6 %	CF site 30-September-2004 Precipitation sum: 389.5 mm Aggregation ratio: 1.3 %	CF site 14-October-2004 Precipitation sum: 396.4 mm Aggregation ratio: 1.7 %

Fig. 44 Image sequence of the inner core unit at the CF site, beginning at 30-April 2004 until 14-October-2004

In the following two weeks the precipitation was 56.4 mm with 42.5 mm precipitation between 17 and 24-June and the aggregation ratio decreased to 8.3 % at 24-June. The soil surface at the CF site appeared at this time visually sealed. Till the next image analysis at 08-July 63 mm precipitation (total precipitation: 159.3 mm) was fallen with 31 mm precipitation between 01 and 07-July. The aggregation ratio decreased at this time to 2 % at the CF site and was visually sealed and crusted. Thereafter the aggregation ratio declined with increasing precipitation to 0.3 % and increased to 1.7 % until 14-October-2004.

The visual assessment of the soil surface exposed that after 16.1 mm precipitation first crusting signs were visible at the soil surface and more pronounced after 39.9 mm precipitation. After a total precipitation of 96.3 mm the soil surface was totally sealed until 2-September. Starting at 16-September the visual analysis revealed that the soil surface sealing was discontinued and a rougher soil surface was visible until October 2004 (Fig. 44). The aggregation ratio in association with the precipitation sum is shown in Fig. 45 to make the dynamic changes more visible.

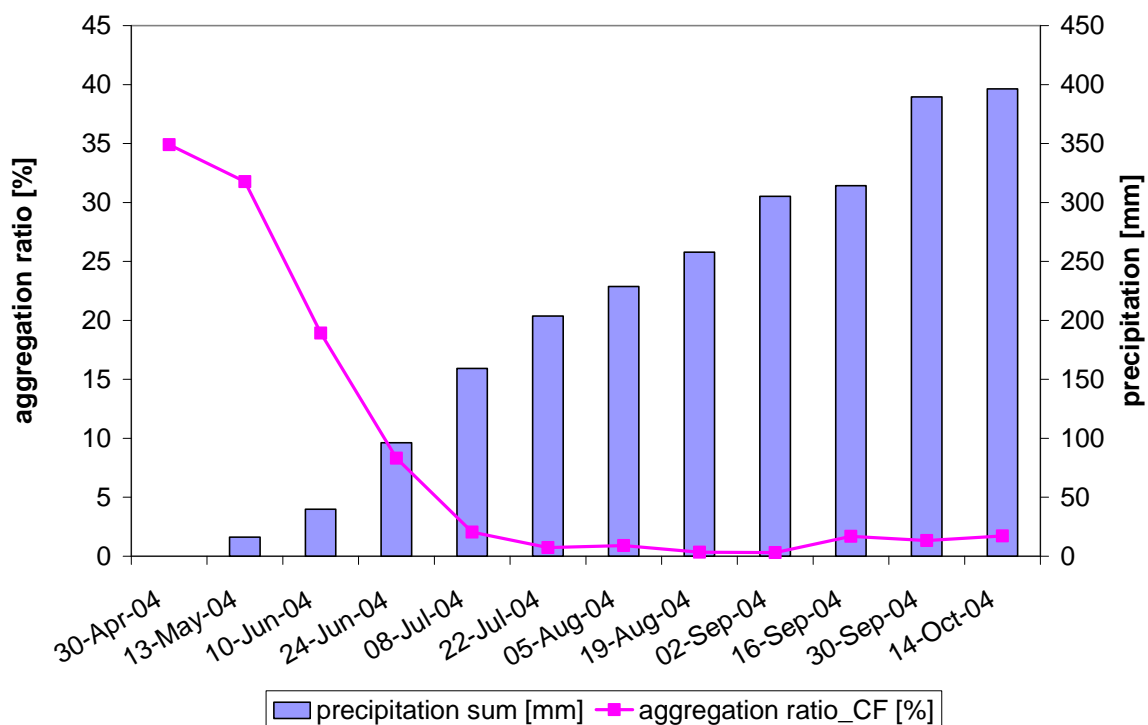





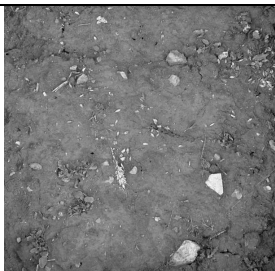




Fig. 45 Precipitation sum and aggregation ratio in 2004 at the CF site, beginning at 30-April-2004 until 14-October-2004

According to the winter wheat cultivation (sowing at 14-November-2004) the soil showed at 13-April a sealed surface without aggregates (aggregation ratio: 0.9 %) due to the 307 mm winter and spring precipitation. After 57.5 mm additional precipitation (maximum intensity: 5.8 mm/h) the aggregation ratio increased to 2.5 % and showed thereafter more or less constant aggregation levels until 07-July. Thereafter the aggregation ratio decreased to

0.6 % after an additional precipitation sum of 145.6 mm (maximum precipitation intensity: 12.7 mm/h) and increased to 6.7 % until 03-August (additional precipitation sum: 225.6 mm; maximum precipitation intensity: 5.1 mm/h) and declined after an additional precipitation sum of 259.7 mm (maximum intensity of 10.6 mm/h) to 3.3 % at 17-August-2005. The visual assessment of the CF soil surface exposed that beginning from the first image the soil surface was totally sealed but showed a notable increasing soil surface roughness at 3-August (Fig. 46). The image analysis at the CF site stopped at 17-August-2005 because of the following harvest at 18-August-2005.

			
CF site 13-April-2005 Precipitation sum: 0.0 mm* Aggregation ratio: 0.9 %	CF site 11-May-2005 Precipitation sum: 57.5 mm* Aggregation ratio: 2.5 %	CF site 25-Mai-2005 Precipitation sum: 68.1 mm* Aggregation ratio: 2.8 %	CF site 08-June-2005 Precipitation sum: 91.5 mm* Aggregation ratio: 2.9 %
			
CF site 07-July-2005 Precipitation sum: 129.3 mm* Aggregation ratio: 2.5 %	CF site 20-July-2005 Precipitation sum: 145.6 mm* Aggregation ratio: 0.6 %	CF site 03-August-2005 Precipitation sum: 225.6 mm* Aggregation ratio: 6.7 %	CF site 17-August-2005 Precipitation sum: 259.7 mm* Aggregation ratio: 3.3 %

*To get the real precipitation sum which reached the soil surface, the precipitation fallen between sowing in fall 2004 and the first image analysis (307 mm) should be added to the precipitation sum shown under each image

Fig. 46 Image sequence of the inner core unit at the CF site, beginning at 13-April-2005 until 17-August 2005

To make these changes more visible, the aggregation ratio in combination with the precipitation sum (starting from the first image analysis) as well as the total precipitation impact (in mm) to the soil surface after sowing in fall 2004 is shown in Fig. 47.

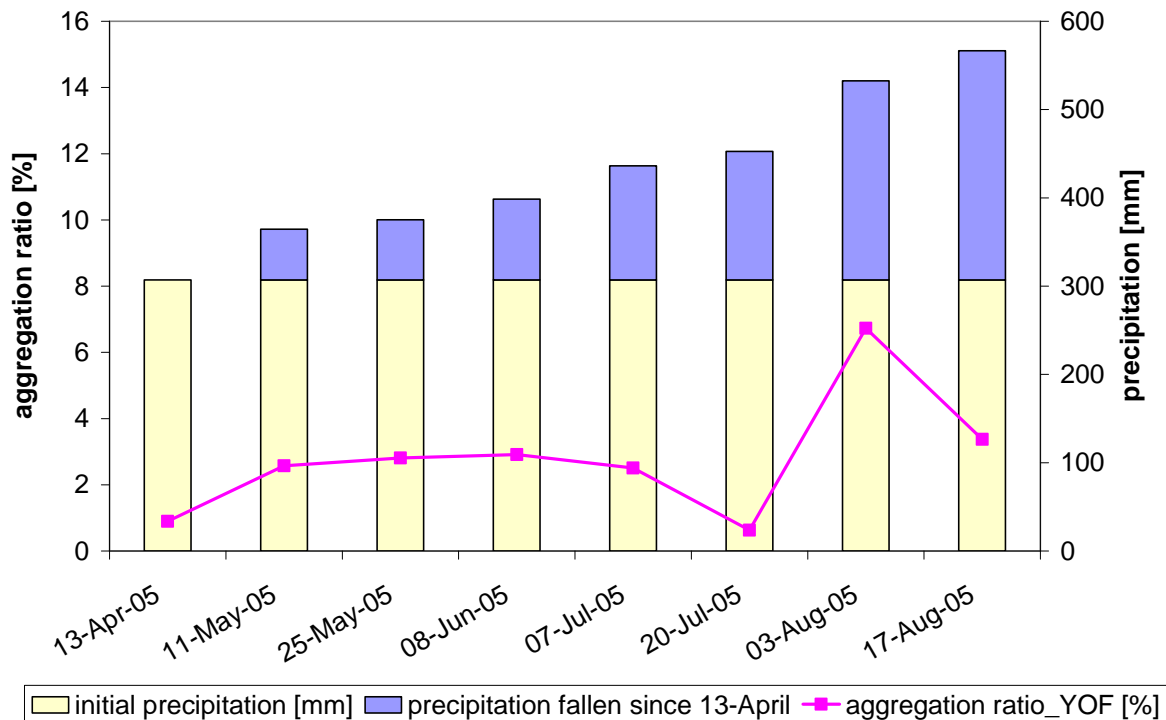


Fig. 47 Initial precipitation fallen from the last cultivation in fall 2005 until first image analysis as well as precipitation fallen after the first image analysis and aggregation ratio in 2005 at the CF site

4.2.3.8 Correlation statistics

In Table 9 the correlation coefficients as well as the significance level between acid-phosphatase, β -glucosidase activity and biotic and abiotic factors were shown. The enzyme activities showed positive and sometimes negative correlations to the aggregation ratio at the $P < 0.05$ level or were not significant correlated. The Cmic and Corg contents as well as the precipitation sum were in general significant and positively correlated to both enzymes. In contrast the pH-value was negative and mostly significant correlated to the enzymes. However the other factors such as Cmic/Corg ratio, nitrogen content, C/N ratio, soil moisture, and soil temperature (as seven day moving average) were positively correlated at different significant levels and showed sometimes no significance to the enzyme activity.

Table 9 Correlation coefficients (R)^a between enzyme activities^b and biotic and abiotic parameters^c at the CF site for 2004, 2005 and 2004/2005

variable	site	acid-phosphatase			β-glucosidase		
		2004	2005	2004/2005	2004	2005	2004/2005
aggregation ratio	CF	-0.396*	0.378*	-0.325*	-0.363*	0.274 ^{n.s.}	-0.339*
Corg	CF	0.425**	0.594***	0.656***	0.490**	0.727***	0.696***
Cmic	CF	0.721***	0.562***	0.682***	0.658***	0.533***	0.626***
Cmic/Corg ratio	CF	0.708***	0.304 ^{n.s.}	0.470**	0.632***	0.207 ^{n.s.}	0.372*
nitrogen	CF	0.023 ^{n.s.}	0.501**	0.545***	0.224 ^{n.s.}	0.435**	0.448**
C/N ratio	CF	0.155 ^{n.s.}	0.002 ^{n.s.}	0.230 ^{n.s.}	0.439**	0.363*	0.471**
pH-value	CF	-0.216 ^{n.s.}	-0.584***	-0.593***	-0.435**	-0.601***	-0.622***
moisture	CF	0.409**	0.390*	0.062 ^{n.s.}	0.492**	0.064 ^{n.s.}	0.142 ^{n.s.}
temp	CF	0.286 ^{n.s.}	0.630***	0.383*	0.016 ^{n.s.}	0.279 ^{n.s.}	0.124 ^{n.s.}
precipitation sum	CF	0.486**	0.338*	0.530**	0.715***	0.260 ^{n.s.}	0.320*

^a Level of significance: * P < 0.05, ** P < 0.01, *** P < 0.001, n.s. not significant

^b Acid-phosphatase, β-glucosidase

^c Aggregation ratio, organic carbon content (Corg), microbial carbon content (Cmic), Cmic/Corg ratio, nitrogen content, C/N ratio, pH-value, soil moisture content (moisture), soil temperature as seven day moving average (temp) and precipitation sum

Furthermore correlation coefficients (R) and significance levels between the aggregation ratio and biotic and abiotic factors were shown in Table 10. The aggregation ratio was positive as well negative correlated to the enzyme activities (described above) and the Corg content was not significantly correlated to the Corg content. Positive significant correlations were found to the Cmic content and Cmic/Corg ratio (in 2004 and 2004/2005) as well as negative significant correlations in 2005. The correlations between the aggregation ratio and nitrogen content, C/N ratio, pH-value, soil moisture and soil temperature showed no clear trend during the field experiment (significant as well as not significant positive and negative correlations were found). The total precipitation was in 2004 and 2004/2005 negative and significant correlated to the aggregation ratio and in 2005 negative and significant correlated due to the crusted soil surface at beginning of the image analysis in 2005.

Table 10 Correlation coefficients (R)^a between the aggregation ratio and biotic and abiotic parameters^b at the CF site for 2004, 2005 and 2004/2005

variable	site	Aggregation ratio		
		2004	2005	2004/2005
Pho	CF	-0.396*	0.378*	-0.325*
Glu	CF	-0.363*	0.274 ^{n.s.}	-0.339*
Corg	CF	0.229 ^{n.s.}	-0.007 ^{n.s.}	0.242 ^{n.s.}
Cmic	CF	-0.683***	0.663***	-0.490**
Cmic/Corg	CF	-0.744***	0.588**	-0.609***
nitrogen	CF	0.224 ^{n.s.}	-0.579***	0.223 ^{n.s.}
C/N ratio	CF	-0.052 ^{n.s.}	0.602***	-0.203 ^{n.s.}
pH-value	CF	0.808***	-0.176 ^{n.s.}	0.493**
moisture	CF	-0.708***	-0.229 ^{n.s.}	-0.595**
temp	CF	-0.469**	0.345*	0.248 ^{n.s.}
precipitation sum	CF	-0.818***	0.595***	-0.543**

^a Level of significance: * P <0.05, ** P <0.01, *** P <0.001, n.s. not significant

^b Acid-phosphatase (Pho), β -glucosidase (Glu), organic carbon content (Corg), microbial carbon content (Cmic), Cmic/Corg ratio, nitrogen content, C/N ratio, pH-value, soil moisture content (moisture), soil temperature as seven day moving average (temp) and precipitation sum

4.3 Rainfall experiment

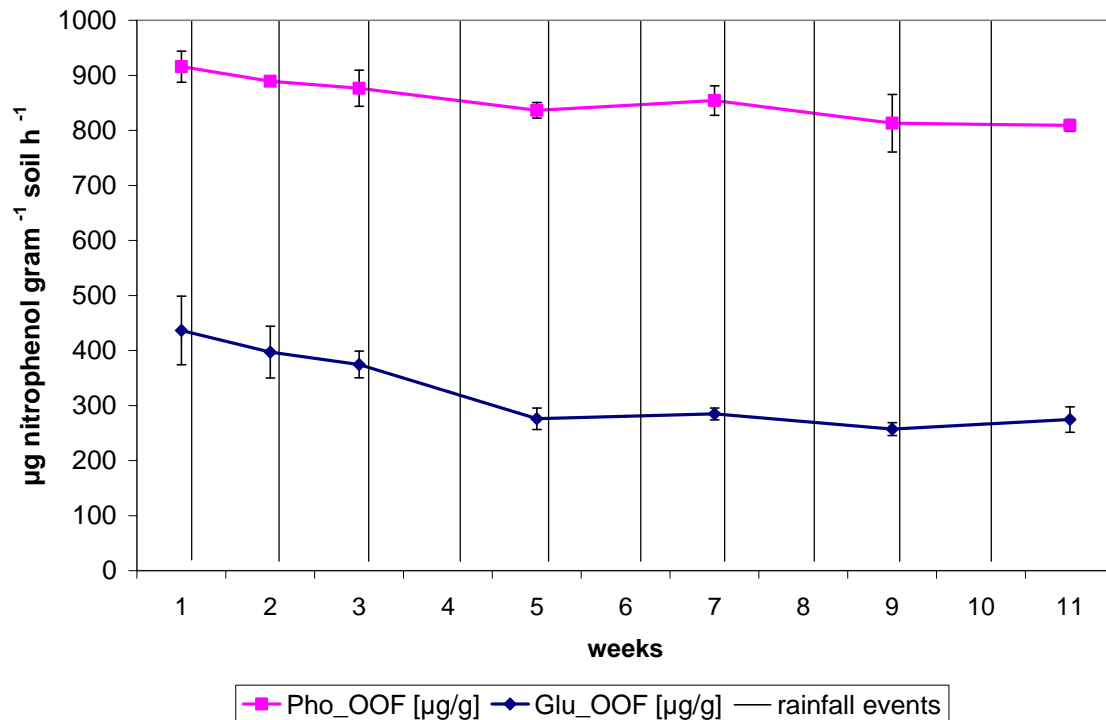
Environmental conditions

The rainfall tower is not equipped with air condition to control air temperature and moisture. Despite of these conditions, soil temperature (as seven day moving average) showed only moderate variations, ranging from 11.9 to 16.6 °C (Annex 2).

4.3.1 Old Organic Farming soil

4.3.1.1 Enzyme activity

The acid-phosphatase activity ranged between 915 $\mu\text{g NP/g}^*\text{h}$ (first sampling) and 809 $\mu\text{g NP/g}^*\text{h}$ (last sampling) with an average mean of 849 $\mu\text{g NP/g}^*\text{h}$. The activity of β -glucosidase was at the initial sampling (before the first rainfall event) 436 $\mu\text{g NP/g}^*\text{h}$ and showed as well as the phosphatase activity a decreasing trend until the last sampling. The β -glucosidase activity ranged between 436 $\mu\text{g NP/g}^*\text{h}$ and 256 $\mu\text{g NP/g}^*\text{h}$ with an average mean of 313 $\mu\text{g NP/g}^*\text{h}$ (Fig. 48). The regression analysis revealed a positive significant correlation ($R=0.933$) at the $P<0.001$ level between acid-phosphatase and β -glucosidase.



Error bars indicate the standard deviation between 6 replications

Fig. 48 Enzyme activity of acid-phosphatase (Pho) and β -glucosidase (Glu) at the OOF soil during the rainfall experiment

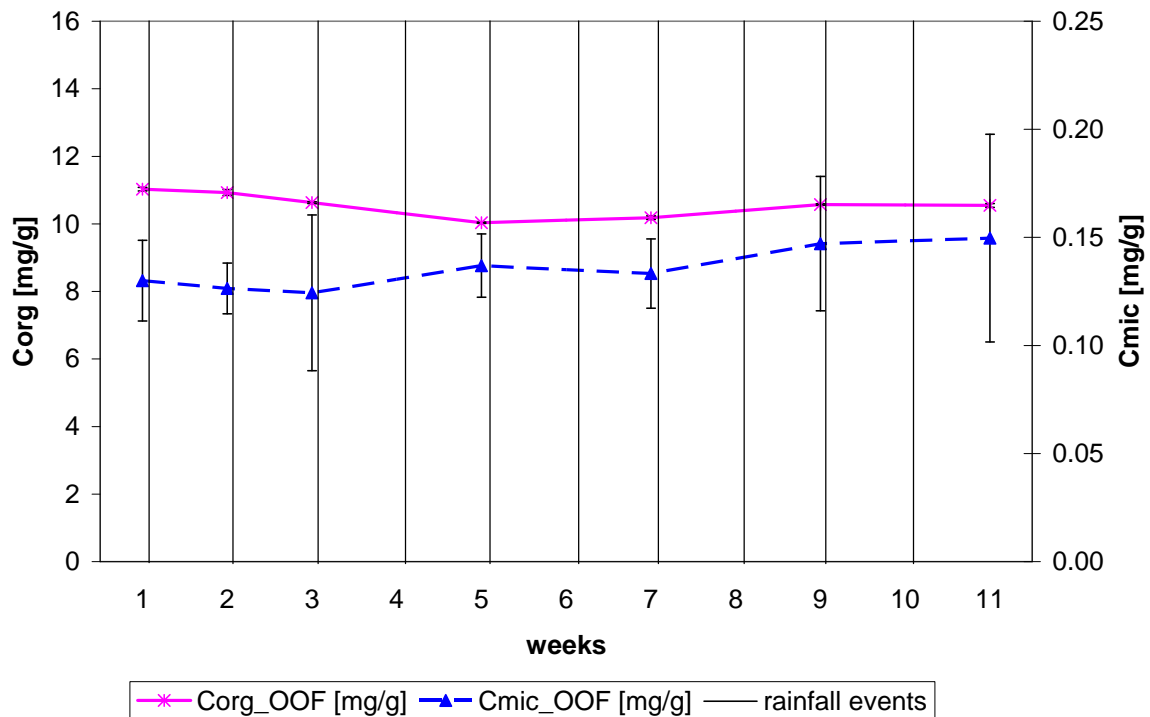
4.3.1.2 Carbon

Organic carbon (Corg)

The organic carbon content changed during the rainfall between 11.0 and 10.0 mg/g whereas the arithmetic mean was 10.5 mg/g. During the whole rainfall experiment a general decreasing tendency could be found (Fig. 49).

Microbial carbon (Cmic)

The microbial carbon content at the OOF soil during the rainfall event ranged between 0.124 mg/g and 0.150 mg/g with an arithmetic of 0.137 mg/g. Due to the error bars no positive or negative tendency could be found for the microbial carbon content during the rainfall experiment (Fig. 49).



Error bars indicate the standard deviation between 3 replications (error bars for Corg not visible)

Fig. 49 Organic carbon content (Corg) and microbial carbon content (Cmic) at the OOF soil during the rainfall experiment

Cmic/Corg ratio

The Cmic/Corg ratio at the OOF soil showed in general an increasing trend beginning from the first until the last sampling. During the whole rainfall experiment the Cmic/Corg ratio ranged between 1.2 % and 1.4 % (Fig. 50).

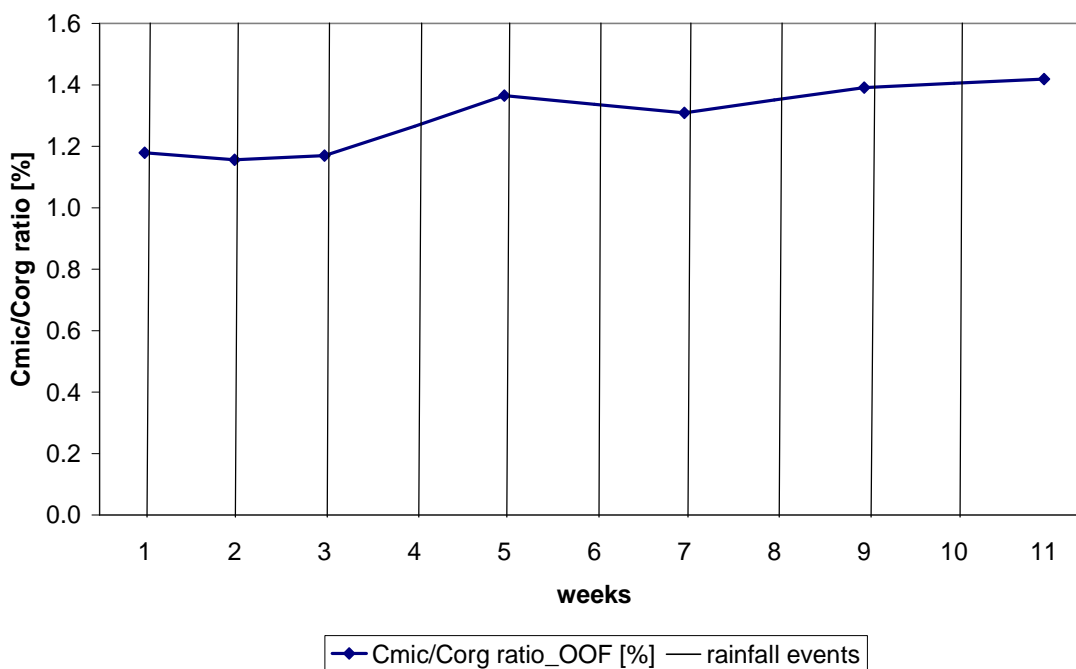
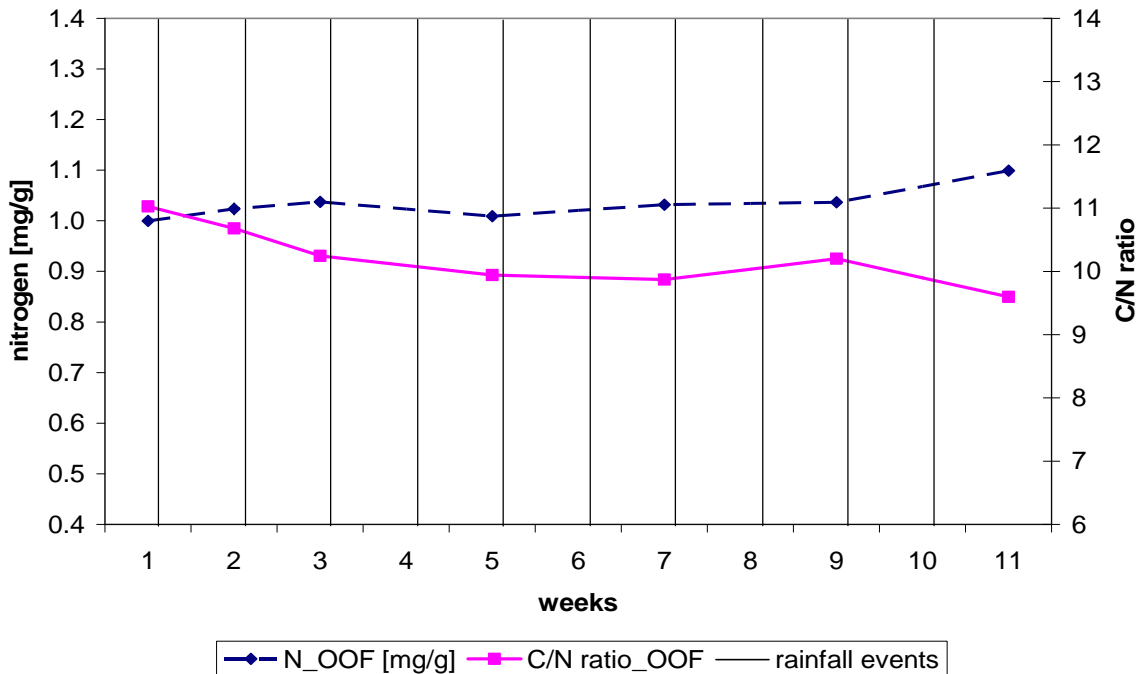


Fig. 50 Cmic/Corg ratio at the OOF soil during the rainfall experiment

4.3.1.3 Nitrogen and C/N ratio

The nitrogen content at the OOF soil was 1.0 mg/g at the first soil sampling and increased stepwise to 1.1 mg/g until the last sampling. At the OOF soil the C/N ratio ranged during the rainfall experiment between 11.0 and 9.6 and showed in general a decreasing tendency with increasing number of rainfall events (Fig. 51).



Error bars indicate the standard deviation between 3 replications (not visible)

Fig. 51 Nitrogen content and C/N ratio at the OOF soil during the rainfall experiment

4.3.1.4 pH-value

The pH-value during the rainfall experiment changed between pH 5.7 and pH 6.2 with an arithmetic mean of pH 5.9 (Fig. 52).

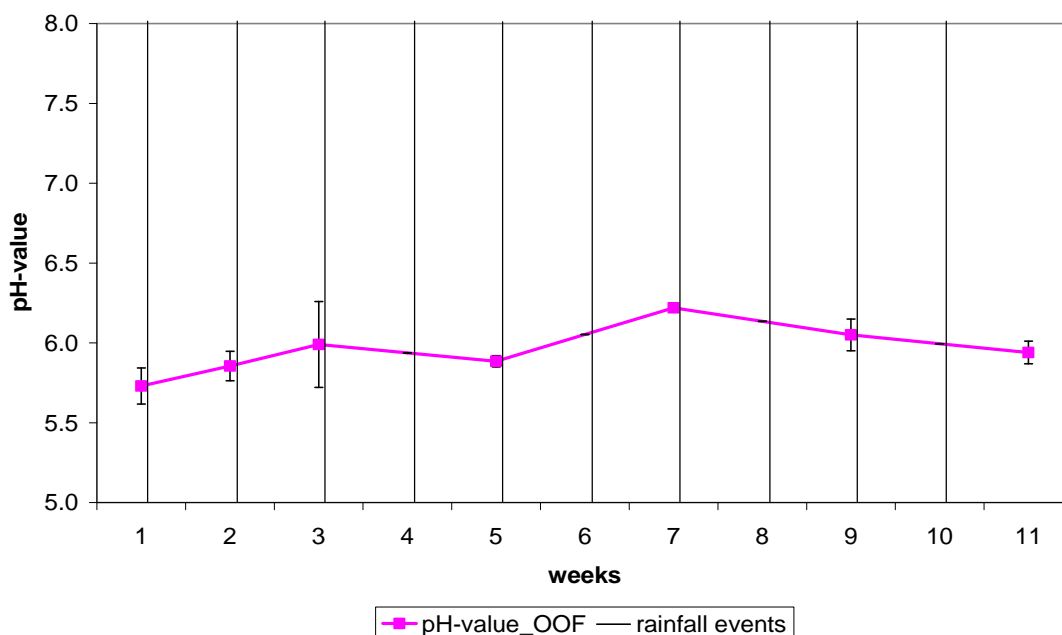


Fig. 52 pH-value at the OOF soil during the rainfall experiment

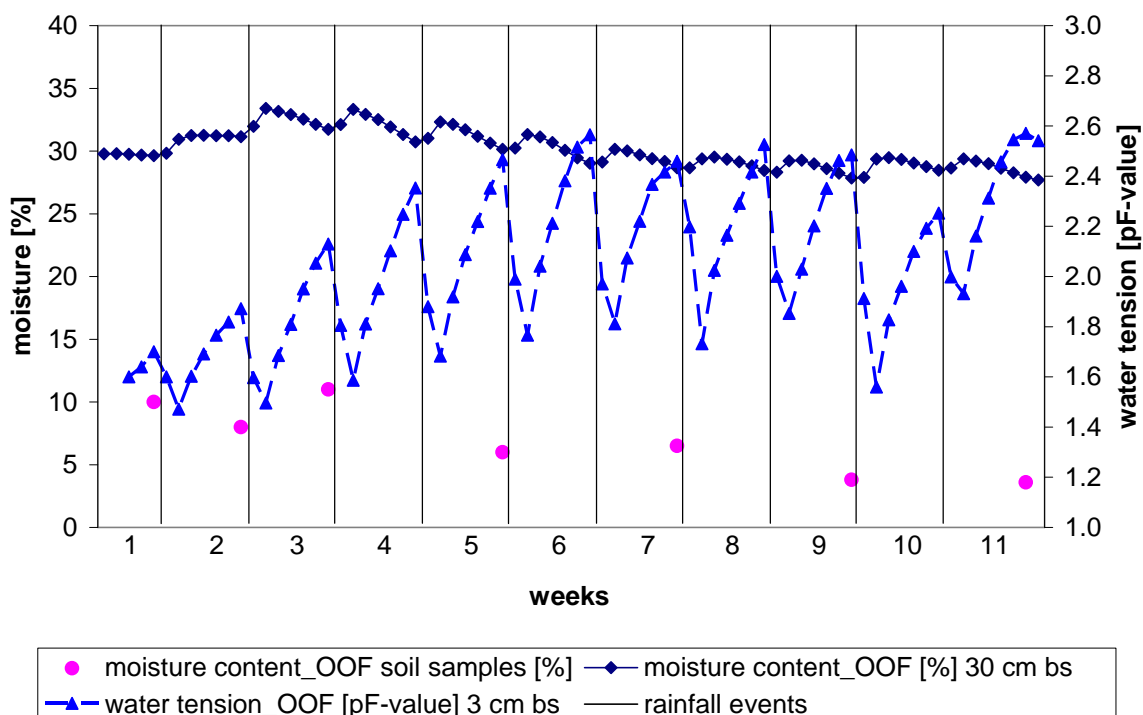
4.3.1.5 Soil water

Soil moisture content

The soil moisture content was analyzed in two different ways at the laboratory rainfall experiment as described in the material and methods part.

Primarily: The soil moisture content was measured gravimetrically on soil samples (upper 3 three cm of the soil surface) taken for the analysis of biotic and abiotic factors. The soil moisture content at these samples ranged between 11.0 % and 3.6 % with a decreasing tendency until the last sampling (Fig. 53).

Secondly: Thirty centimeters below the soil surface the moisture content was measured continuously with TDR probes (mean of 24 hours) beginning a few days before the first sampling until the last sampling. Before the first rainfall event the water content was at a constant level (29.6 %) and rose after the first rainfall event to 31.1 % and after the second to 33.4 %. During the rainfall events (with exception of the first rainfall event) the water content decreased (due to the suction plates which were installed at the bottom of each soil box) and increased after each rainfall event. Generally the water content during the whole experimental period ranged between 27.8 % and 33.4 % with a decreasing tendency during the rainfall experiment (Fig. 53).



* taken from the upper 3 cm of the soil surface

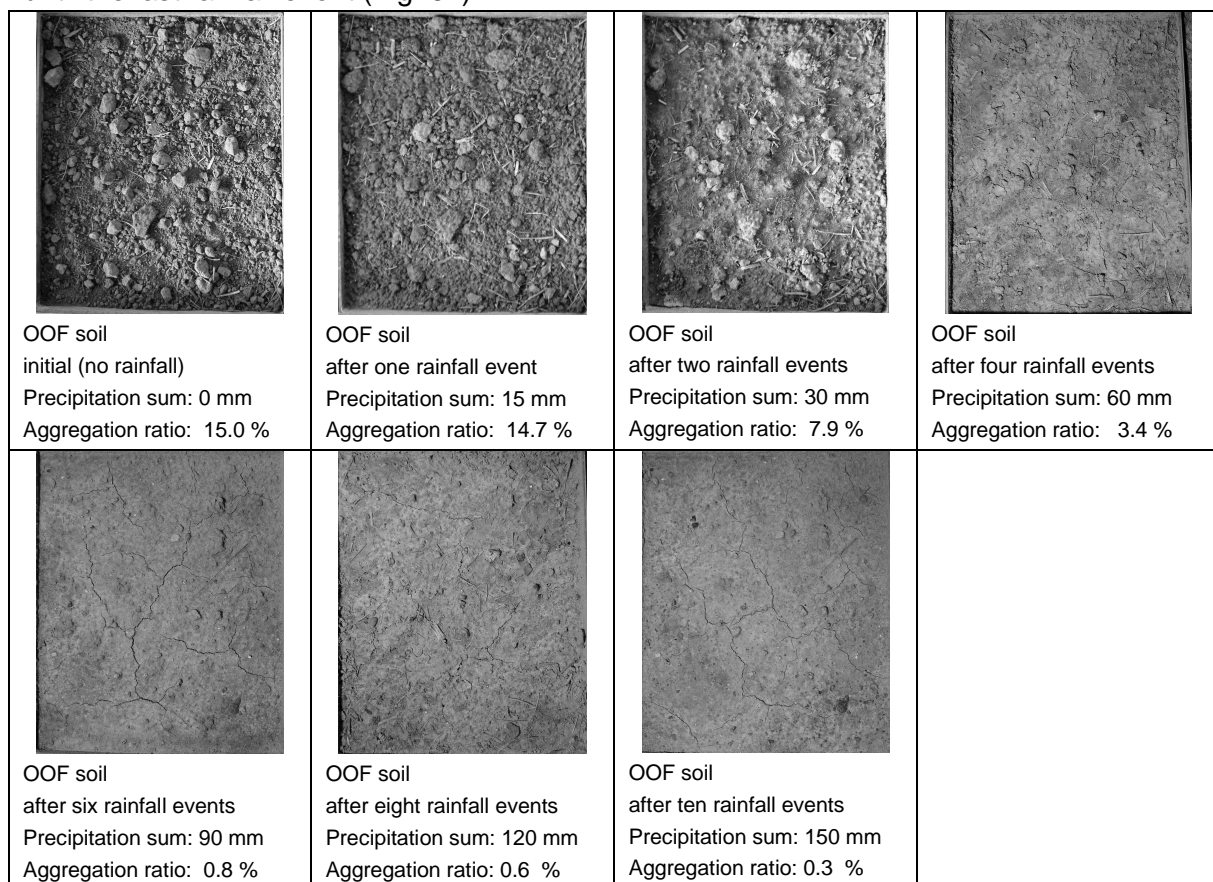
Fig. 53 Soil moisture content of the OOF soil samples*, soil moisture content 30 cm below the soil surface (bs) as well as water tension 3 cm below the soil surface (bs) during the rainfall experiment

Matric potential

The soil water tension 3 cm below the soil surface was measured with tensiometer, equitensiometer and gypsum block sensors every day in 30 minutes intervals. Subsequent the mean of 24 hours was calculated. Due to the water tension range and the probe design the tensiometer probes reached the best measured values and the highest resolution. Therefore the data of the tensiometer probes were shown exclusively. The pF-value ranged between dry soil conditions (e.g. pF 2.75) and moist soil conditions (e.g. pF 1.47). In general it could be observed that the water tension decreased until two days after the rainfall event and increased thereafter until the next rainfall event. Furthermore an increasing pF tendency could be found during the experimental period (Fig. 53).

4.3.1.6 Soil surface roughness

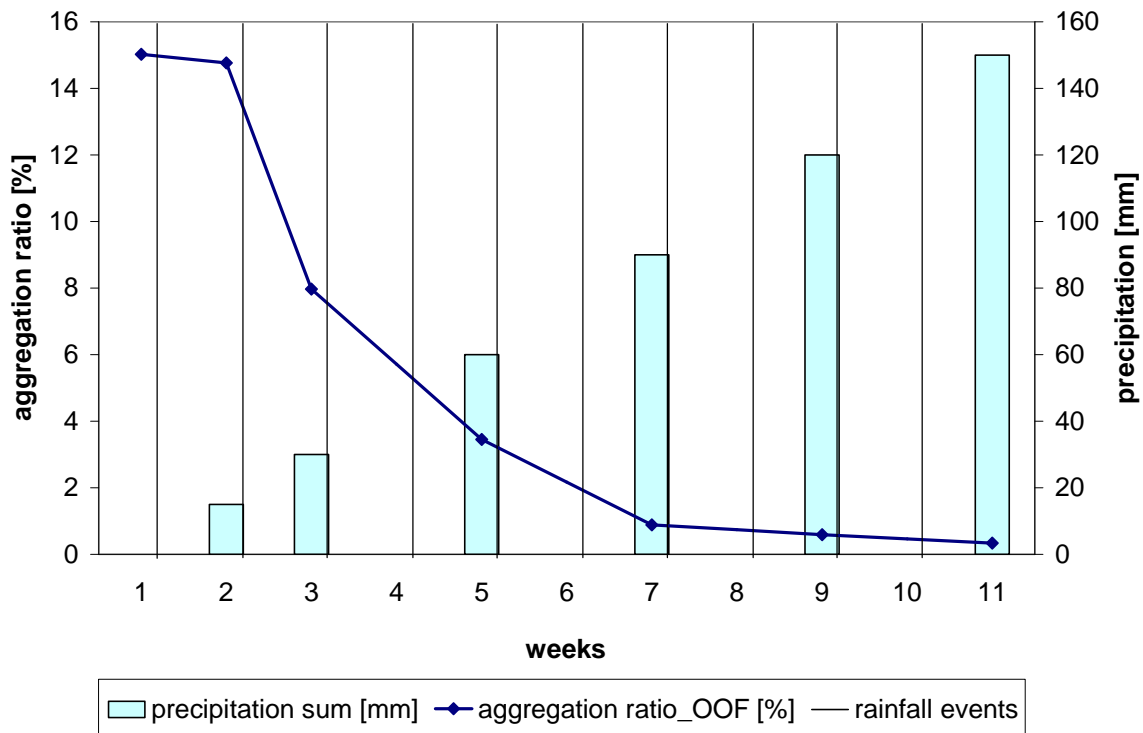
The initial aggregation ratio at the soil surface of the OOF soil box 1 was 15.0 % and decreased to 14.7 % after 15 mm precipitation. After a total rainfall of 30 mm the aggregation ratio declined to 7.9 mm and to 3.4 % after 60 mm precipitation. After the sixth rainfall event the aggregation ratio was 0.8 %, decreased to 0.6 % after 120 mm precipitation and to 0.3 % after the tenth rainfall event. The visual analysis of the soil surface revealed that after 30 mm precipitation the soil surface showed first sealing signs and was crusted after 60 mm rainfall until the last rainfall event (Fig. 54).



*soil box 1

Fig. 54 Image sequence of the inner core unit at the OOF soil surface* during the rainfall experiment

In Fig. 55 the dynamic aggregation ratio changes during the rainfall experiment in relation to the rainfall sum is shown.

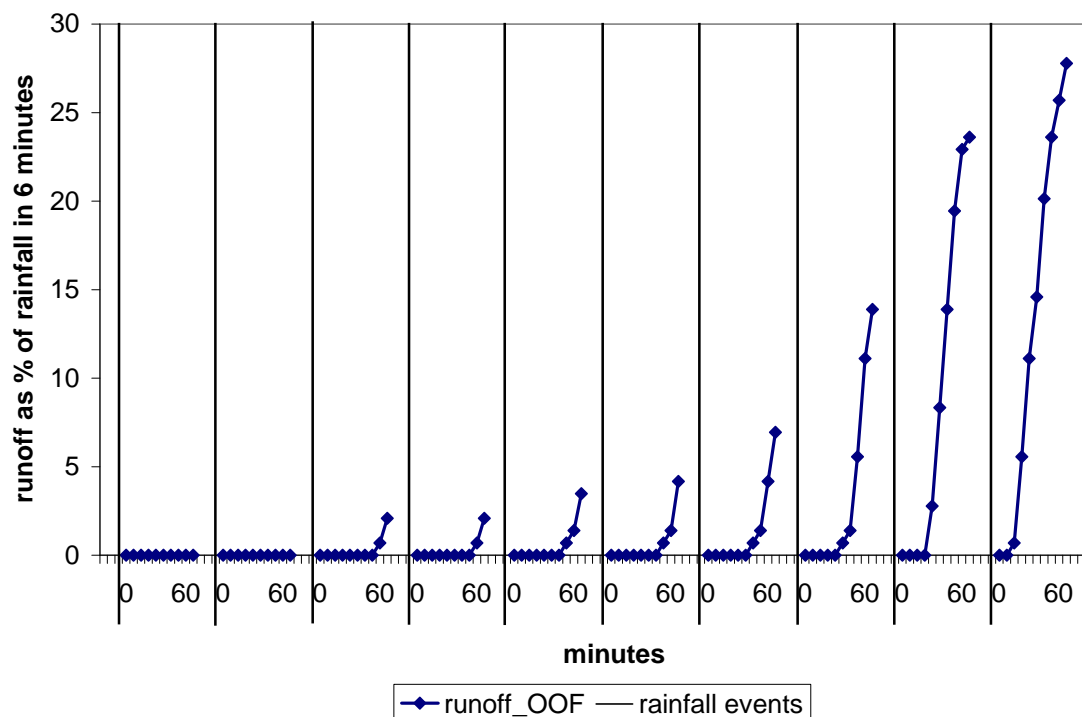


* soil box 1

Fig. 55 Precipitation sum as well as aggregation ratio at the OOF soil surface* during the rainfall experiment

4.3.1.7 Runoff

The runoff formation at the inner core unit of the OOF soil box 1 is shown in Fig. 56. During the first and the second rainfall event no runoff could be measured. At the third and fourth rainfall event the runoff started slowly with 0.7 % of rainfall (fallen in 6 minutes) among the 48 and 54 minute and reached 2.1 % of rainfall between the 54 and 60 minute. At the fifth and sixth rainfall event the runoff at the soil surface started between the 42 and 48 minute with 0.7 % and rose to 3.5 % at the fifth and 4.2 % at the sixth rainfall between the 54 and 60 minute. At the seventh rainfall experiment the runoff started between the 36 and 42 minute (0.7 % of rainfall) and at the eighth rainfall between the 30 and 36 minute (0.7 % of rainfall) and reached among the 54 and 60 minute 6.3 % at the seventh and 13.9 % at the eighth rainfall event. At the ninth rainfall event the runoff started between the 24 and 30 minute and reached between the 54 and 60 minute 23.6 % of rainfall. At the last rainfall experiment the runoff at the OOF site started among the 12 and 18 minute (0.7 % from rainfall) increased between the 36 and 42 minute to 20.1 % and reached between the 54 and 60 minute an amount of 27.8 % of rainfall (Fig. 56).



The runoff was measured in 6 minutes intervals during each 60 minutes rainfall event. After each rainfall event the soil surface was dried for duration of six days. At the seventh day the next rainfall event was conducted.

Fig. 56 Runoff during the rainfall events at the OOF soil surface (6 % slope) as % of rainfall fallen in 6 minutes

4.3.1.8 Correlation statistics

At the rainfall experiment the enzyme activity showed positive and significant correlations to the aggregation ratio as well as to the soil moisture content. Negative significant correlations were found to the Cmic content, Cmic/Corg ratio, nitrogen content, pH-value and to the precipitation sum. No significant correlations were observed to the Corg content as well as to the soil temperature as seven day moving average (Table 11).

Furthermore the SAS linear regression model was conducted between the aggregation ratio at the soil surface and the variables shown in Table 12. Therefore positive significant correlations could be found to the enzyme activities, C/N ratio and to the soil moisture content. Negative significant correlations were revealed to the Cmic content, Cmic/Corg content, nitrogen content, pH-value, total rainfall as well as to the rainfall runoff ratio. No significant correlation could be found between the aggregation ratio and the Corg content as well as to the soil temperature.

Table 11 Correlation coefficients (R)^a between enzyme activities^b and biotic and abiotic parameters^c at the OOF soil during the rainfall experiment

rainfall experiment			
variable	site	acid-phosphatase	β -glucosidase
aggregation ratio	OOF	0.914***	0.949***
Corg	OOF	-0.137 ^{n.s.}	-0.138 ^{n.s.}
Cmic	OOF	-0.871***	-0.810***
Cmic/Corg ratio	OOF	-0.937***	-0.955***
nitrogen	OOF	-0.653***	-0.412**
C/N ratio	OOF	0.629***	0.379*
pH-value	OOF	-0.497**	-0.534**
moisture	OOF	0.891***	0.830***
temp	OOF	0.003 ^{n.s.}	-0.166 ^{n.s.}
precipitation sum	OOF	-0.938***	-0.853***
rainfall/runoff ratio	OOF	-0.679***	-0.638***

^a Level of significance: * P <0.05, ** P <0.01, *** P <0.001, n.s. not significant

^b Acid-phosphatase, β -glucosidase

^c Aggregation ratio, organic carbon (Corg) content, microbial carbon (Cmic) content, Cmic/Corg ratio, nitrogen content, C/N ratio, pH-value, soil moisture content (moisture), soil temperature as seven day moving average (temp), precipitation sum and rainfall/runoff ratio

Table 12 Correlation coefficients (R)^a between the aggregation ratio and biotic and abiotic parameters^b at the OOF site during the rainfall experiment

rainfall experiment		
variable	site	aggregation ratio
Pho	OOF	0.914***
Glu	OOF	0.949***
Corg	OOF	-0.046 ^{n.s.}
Cmic	OOF	-0.744***
Cmic/Corg	OOF	-0.892***
nitrogen	OOF	-0.560**
C/N ratio	OOF	0.567**
pH-value	OOF	-0.726***
moisture	OOF	0.762***
temp	OOF	-0.151 ^{n.s.}
precipitation sum	OOF	-0.906***
rainfall/runoff ratio	OOF	-0.586**

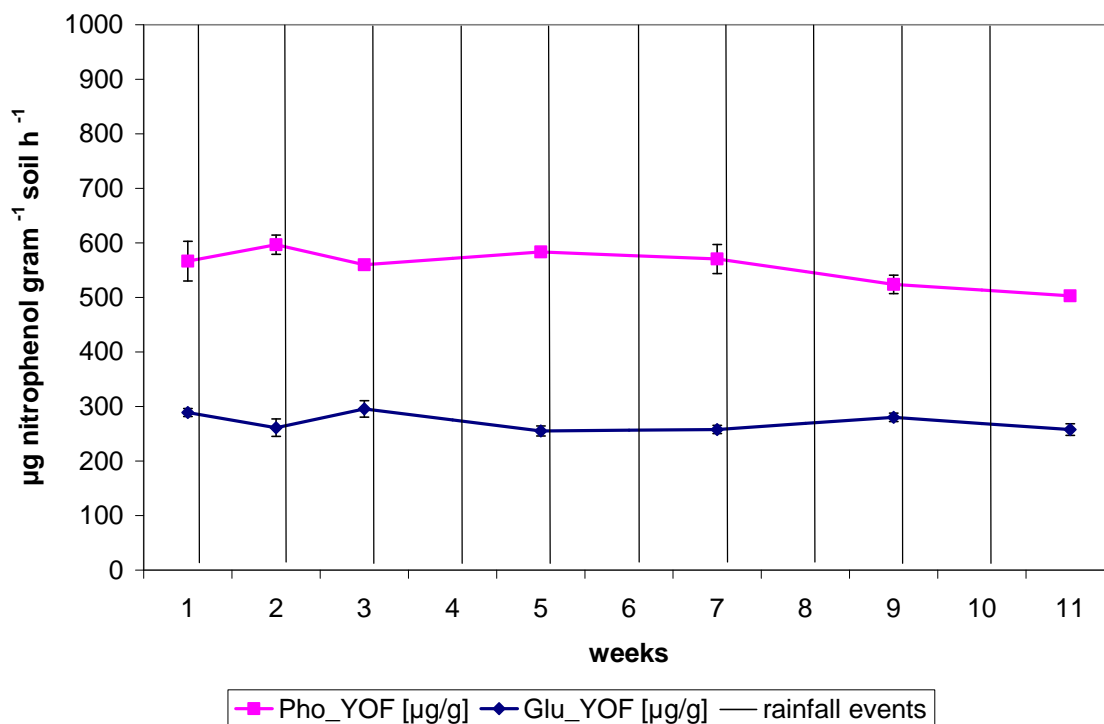
^a Level of significance: * P <0.05, ** P <0.01, *** P <0.001, n.s. not significant

^b Acid-phosphatase (Pho), β -glucosidase (Glu), organic carbon (Corg) content, microbial carbon (Cmic) content, Cmic/Corg ratio, nitrogen content, C/N ratio, pH-value, soil moisture content (moisture), soil temperature as seven day moving average (temp), precipitation sum and rainfall/runoff ratio

4.3.2 Young Organic Farming soil

4.3.2.1 Enzyme activity

The YOF soil showed before the first rainfall event an activity rate of 566 $\mu\text{g NP/g}^*\text{h}$ for acid-phosphatase and 288 $\mu\text{g NP/g}^*\text{h}$ for β -glucosidase. In general a decreasing trend could be observed for the enzyme activities during the whole rainfall experiment. The enzyme activity was seven days after the last rainfall 503 $\mu\text{g NP/g}^*\text{h}$ acid-phosphatase and 257 $\mu\text{g NP/g}^*\text{h}$ for β -glucosidase (Fig. 57).



Error bars indicate the standard deviation between 6 replications

Fig. 57 Enzyme activity of acid-phosphatase (Pho) and β -glucosidase (Glu) at the YOF soil during the rainfall experiment

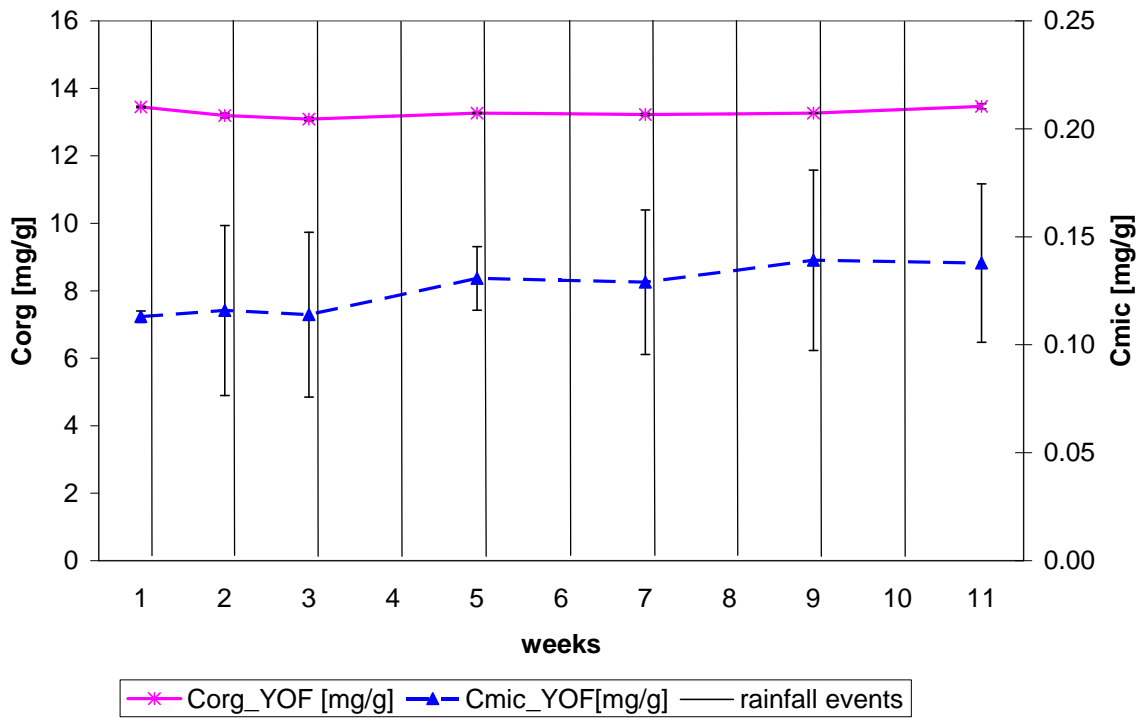
4.3.2.2 Carbon

Organic carbon (Corg)

During the rainfall experiment the Corg content was at a more or less constant level with a range between 13.09 mg/g and 13.47 mg/g at the YOF soil (Fig. 58).

Microbial carbon (Cmic)

The microbial content ranged at the YOF soil between 0.11 mg/g and 0.13 mg/g and showed due to the error bars in general a more or less constant level during the rainfall experiment (Fig. 58).



Error bars indicate the standard deviation between 3 replications (error bars for Corg not visible)

Fig. 58 organic carbon (Corg) content and microbial carbon (Cmic) at the YOF soil during the rainfall experiment

Cmic/Corg ratio

At the rainfall experiment the Cmic/Corg ratio showed an increasing tendency with increasing number of rainfall events. The Cmic/Corg ranged in general between 0.8 % and 1.1 % and showed an average mean of 1.0 % (Fig. 59).

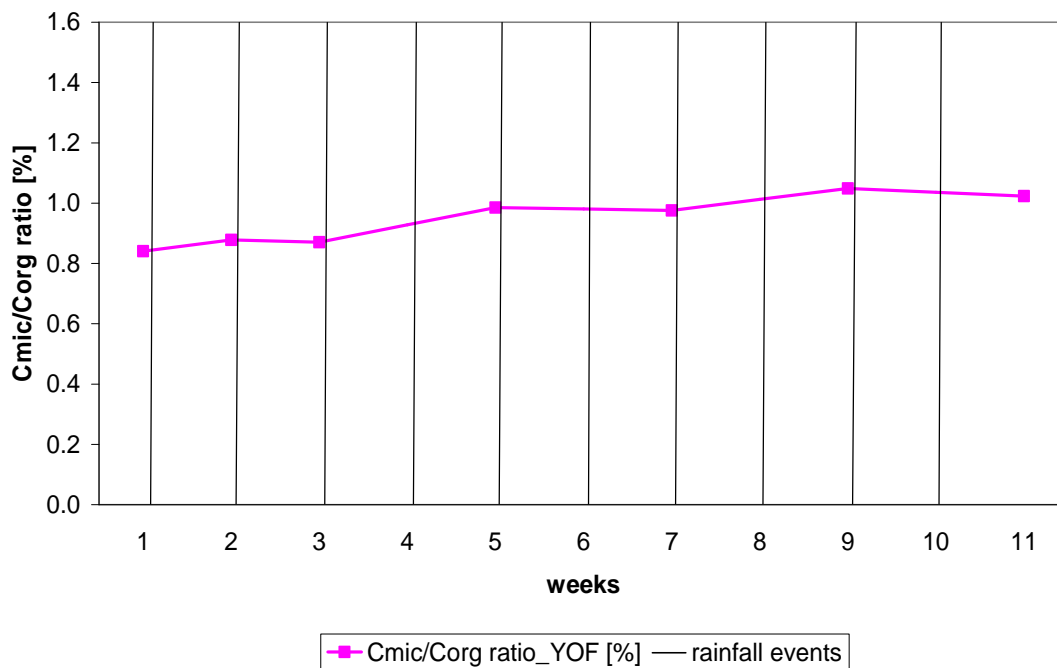
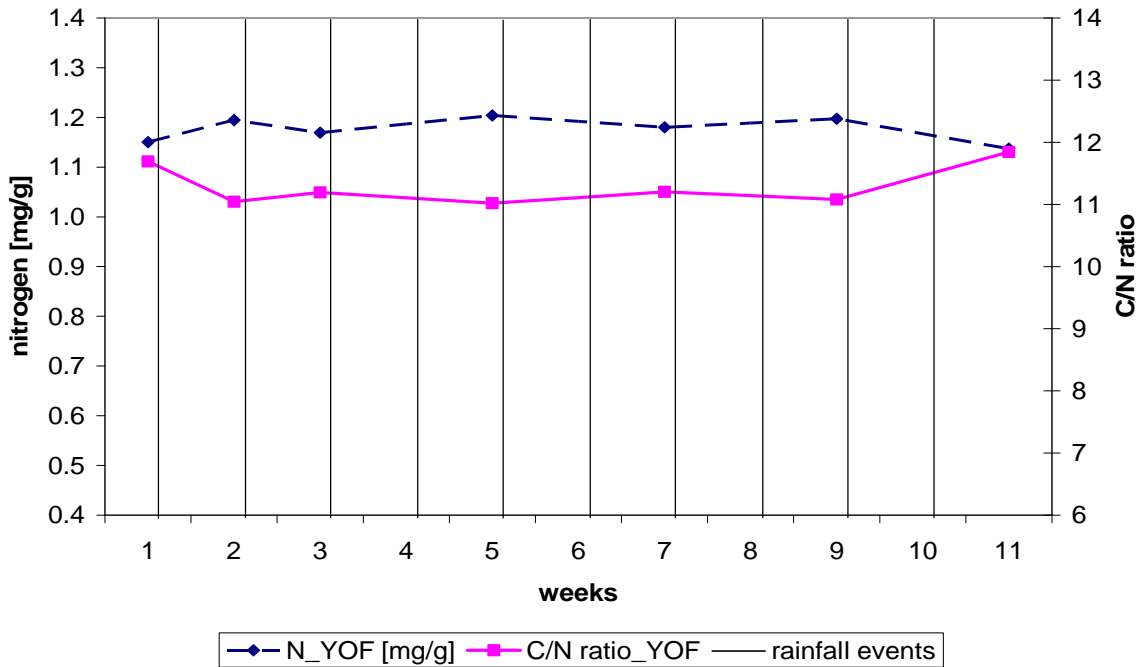


Fig. 59 Cmic/Corg ratio at the YOF soil during the rainfall experiment

4.3.2.3 Nitrogen and C/N ratio

The nitrogen content at the YOF soil showed weak dynamic changes during the rainfall experiment with a maximum content of 1.20 mg/g and minimum content of 1.14 mg/g. The C/N ratio showed as well as the nitrogen content nearly constant conditions. The C/N ratio ranged between C/N=11.7 and C/N=11.0 during the whole experimental period (Fig. 60).



Error bars indicate the standard deviation between 3 replications (not visible)

Fig. 60 Nitrogen content and C/N ratio at the YOF soil during the rainfall experiment

4.3.2.4 pH-value

During the rainfall experiment the pH-value showed in general an increasing tendency and ranged in the upper 3 cm of the YOF soil surface between pH=7.1 and pH=7.4 (Fig. 61).

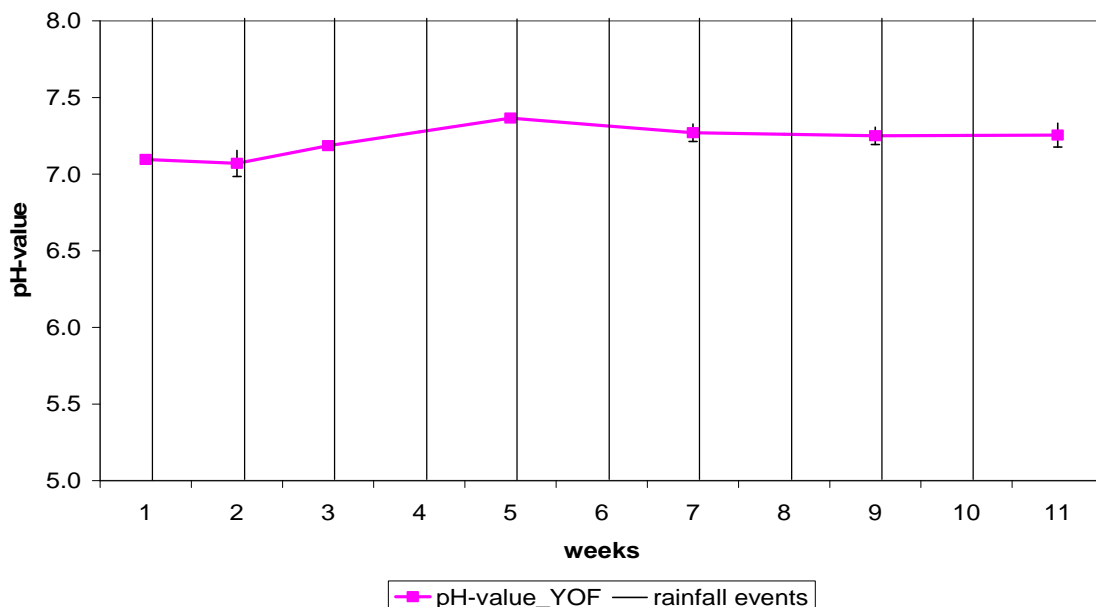
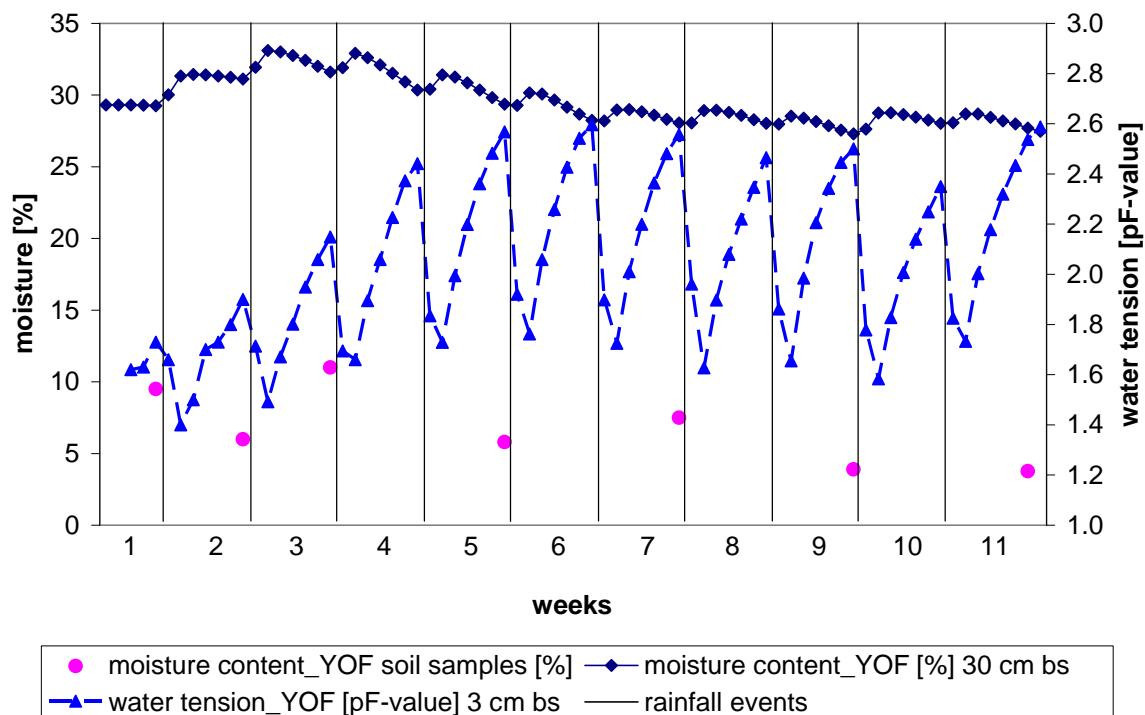


Fig. 61 pH-value at the YOF soil during the rainfall experiment

4.3.2.5 Soil water

Soil moisture content

The gravimetrically measured soil moisture of the soil samples ranged between 11.0 % and 3.8 % with a general decreasing tendency at the last four sampling times (Fig. 62). The continuous measured water content 30 cm (mean of 24 hours) below the soil surface (bs) was previous to the first rainfall event more or less at a constant level (29.3 %) and increased after the first rainfall event to 31.4 % and after the second rainfall event to 33.1 %. In general the water content decreased during the rainfall events (with exception of the first rainfall event) due to the installed suction plates at the bottom of each soil box and increased after each rainfall. In general the water content during the rainfall experiment ranged between 33.1 % and 27.3 % and showed a decreasing tendency with increasing number of rainfall events (Fig. 62).



*taken from the upper 3 cm of the soil surface

Fig. 62 Soil moisture content of the YOF soil samples*, soil moisture content 30 cm below the soil surface (bs) as well as water tension 3 cm below the soil surface (bs) during the rainfall experiment


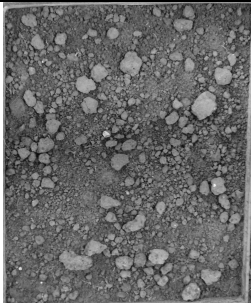
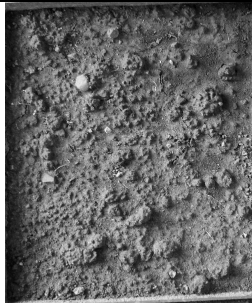
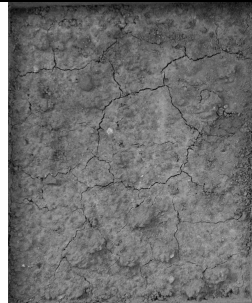


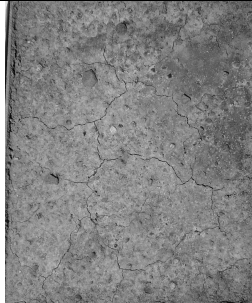
Matric potential

During the whole rainfall experiment the soil water tension was measured with three different water tension devices every 30 minutes. The tensiometer devices showed the best and most consistent datasets and were therefore exclusively shown as mean of 24 hours. The pF-value ranged between dry soil conditions (e.g. pF 2.60) and moist soil conditions (e.g. pF 1.40). In general it could be observed that the water tension decreased until two days after

the rainfall events and increased thereafter until the next rainfall event. Furthermore a general increase during the experimental period could be observed (Fig. 62).

4.3.2.6 Soil surface roughness

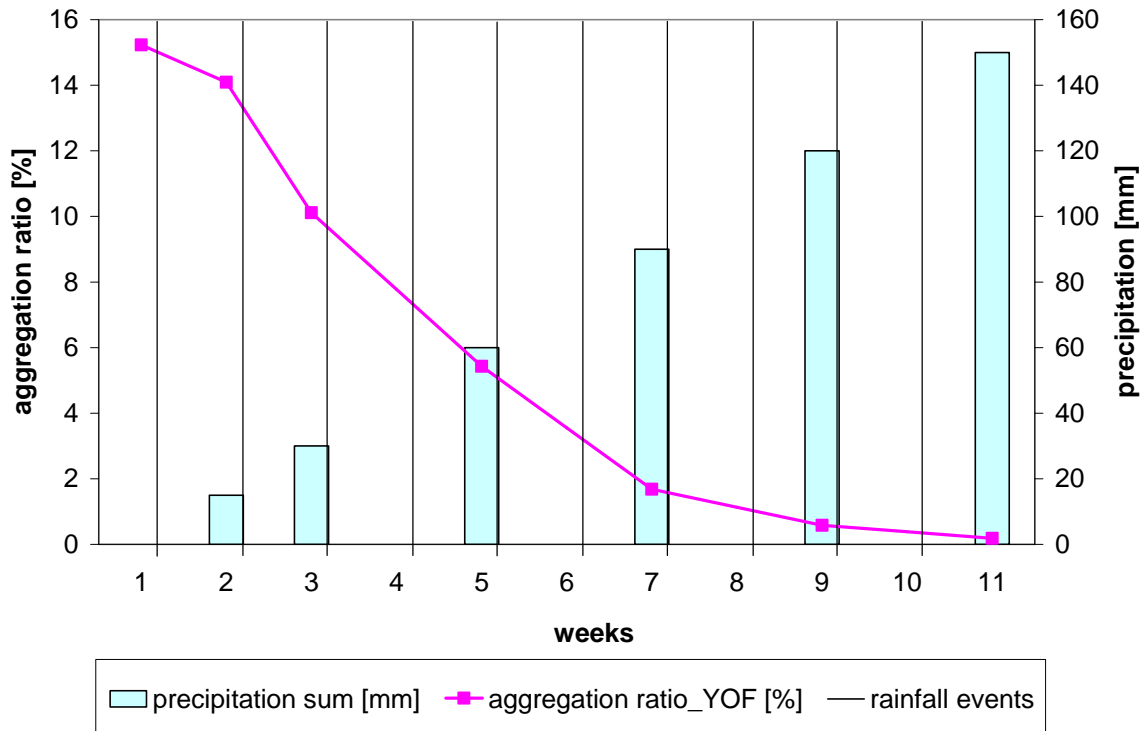
The image analysis at the rainfall experiment showed an initial aggregation ratio of 15.2 % at the YOF site. The aggregation ratio declined to 14.0 % after the first rainfall event and decreased subsequent with increasing number of rainfall events to 0.2 % after 150 mm precipitation. The visual assessment exposed that after 30 mm rainfall the soil surface was initially crusted and after 60 mm rainfall totally crusted until the last image analysis (Fig. 63).

			
YOF soil initial (no rainfall) Precipitation sum: 0 mm Aggregation ratio: 15.2 %	YOF soil after one rainfall event Precipitation sum: 15 mm Aggregation ratio: 14.0 %	YOF soil after two rainfall events Precipitation sum: 30 mm Aggregation ratio: 10.1 %	YOF soil after four rainfall events Precipitation sum: 60 mm Aggregation ratio: 5.4 %
			
YOF soil after six rainfall events Precipitation sum: 90 mm Aggregation ratio: 1.6 %	YOF soil after eight rainfall events Precipitation sum: 120 mm Aggregation ratio: 0.6 %	YOF soil after ten rainfall events Precipitation sum: 150 mm Aggregation ratio: 0.2 %	

* soil box 1

Fig. 63 Image sequence of the inner core unit at the YOF soil surface* during the rainfall experiment

The aggregation ratio at the soil surface in combination with the rainfall sum during the rainfall experiment is shown in Fig. 64.

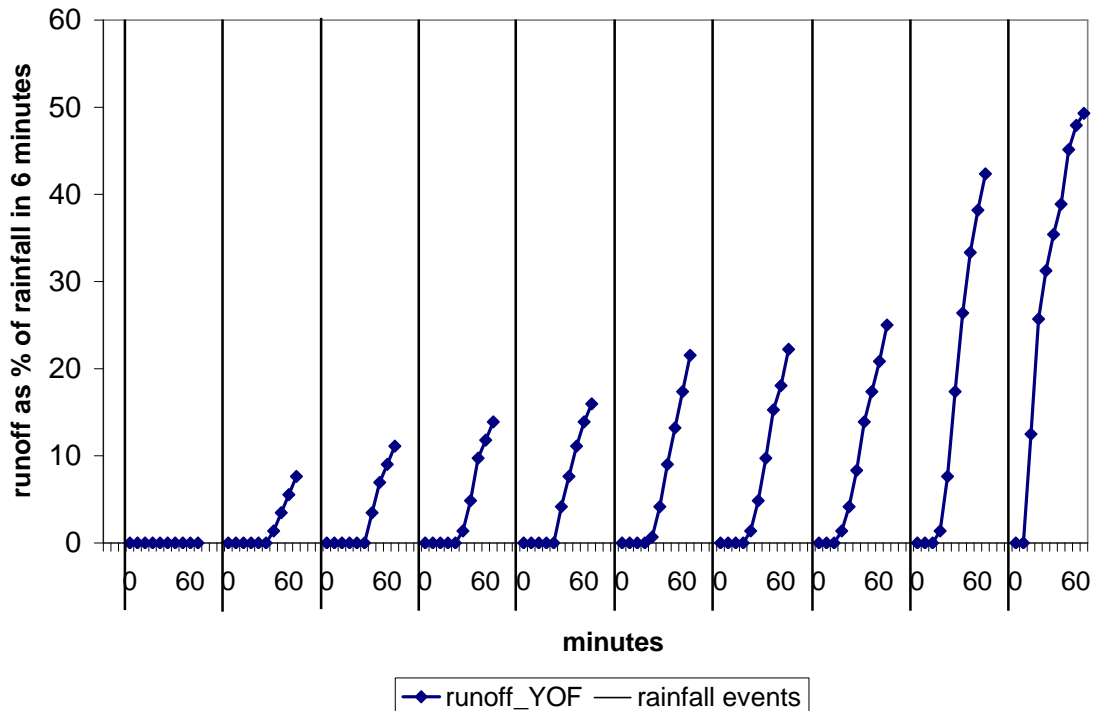


*soil box 1

Fig. 64 Precipitation sum as well as aggregation ratio at the YOF soil surface* during the rainfall experiment

4.3.2.7 Runoff

The runoff at the YOF soil surface started at the second rainfall event between the 36 and 42 minute with 1.4 % of rainfall and reached 7.6 % of rainfall among the 54 and 60 minute. During the third rainfall the runoff started as well at the second rainfall between 36 and 42 minutes but rose to 11.1 % between the 54 and 60 minute. At the fourth and fifth rainfall event the runoff started between 30 and 36 minutes and rose to 13.9 % of rainfall at the fourth and to 16.0 % of rainfall at the fifth rainfall event. During the sixth and seventh period the runoff started among 24 and 30 minutes and reached 21.5 % of rainfall between 54 and 60 minutes at the sixth and 22.2 % at the seventh rainfall period. At the eighth and ninth period the runoff began during 24 and 30 minutes and reached 25 % of rainfall at the eighth and 42.4 % at the ninth rainfall event during the 54 to 60 minute time interval. At the last rainfall event the runoff started among 12 and 18 minutes and reached the maximum of 49.3 % between the 54 to 60 minutes time interval (Fig. 65).



The runoff was measured in 6 minutes intervals during each 60 minutes rainfall event. After each rainfall event the soil surface was dried for duration of six days. At the seventh day the next rainfall event was conducted.

Fig. 65 Runoff during the rainfall events at the YOF soil surface (6 % slope) as % of rainfall fallen in 6 minutes

4.3.2.8 Correlation statistics

At the rainfall experiment the enzyme activity of acid-phosphatase and β -glucosidase was significant and positive correlated to the aggregation ratio and to the soil moisture in the upper 3 cm of the soil surface. Significant negative correlations were found to the Cmic content, Cmic/Corg ratio and to the precipitation sum. Furthermore the acid-phosphatase activity showed positive significant correlations to the nitrogen content and soil temperature and a negative significant correlation to Corg. No significance could be found to the pH-value. The β -glucosidase was negative and significant correlated to the pH-value and showed moreover no significant correlations to the Corg content, nitrogen content, C/N ratio, soil temperature (as seven day moving average) and to the rainfall/runoff ratio (Table 13).

The aggregation ratio at the YOF site was positive significant correlated to the acid-phosphatase, β -glucosidase activity as well as the soil moisture content. Negative significant correlations were found to the Cmic content, Cmic/Corg ratio, pH-value, rainfall sum and to the rainfall/runoff ratio. No significance was found between the aggregation ratio and the Corg and nitrogen content as well as to the C/N ratio and to the soil temperature (Table 14).

Table 13 Correlation coefficients (R)^a between enzyme activities^b and biotic and abiotic parameters^c at the YOF soil during the rainfall experiment

variable	rainfall experiment		
	site	acid-phosphatase	β-glucosidase
aggregation ratio	YOF	0.659***	0.432**
Corg	YOF	-0.482**	-0.189 ^{n.s.}
Cmic	YOF	-0.657***	-0.510**
Cmic/Corg ratio	YOF	-0.618***	-0.502**
nitrogen	YOF	0.534**	-0.232 ^{n.s.}
C/N ratio	YOF	-0.568***	0.098 ^{n.s.}
pH-value	YOF	-0.271 ^{n.s.}	-0.454**
moisture	YOF	0.452***	0.648***
temp	YOF	0.527***	0.183 ^{n.s.}
precipitation sum	YOF	-0.802***	-0.424**
rainfall/runoff ratio	YOF	-0.569**	-0.076 ^{n.s.}

^a Level of significance: * P <0.05, ** P <0.01, *** P <0.001, n.s. not significant

^b Acid-phosphatase, β-glucosidase

^c Aggregation ratio, organic carbon (Corg) content, microbial carbon (Cmic) content, Cmic/Corg ratio, nitrogen content, C/N ratio, pH-value, soil moisture content (moisture), soil temperature as seven day moving average (temp), precipitation sum and rainfall/runoff ratio

Table 14 Correlation coefficients (R)^a between the aggregation ratio and biotic and abiotic parameters^b at the YOF site during the rainfall experiment

variable	rainfall experiment	
	site	aggregation ratio
Pho	YOF	0.659***
Glu	YOF	0.432**
Corg	YOF	-0.126 ^{n.s.}
Cmic	YOF	-0.938***
Cmic/Corg	YOF	-0.949***
nitrogen	YOF	-0.040 ^{n.s.}
C/N ratio	YOF	0.019 ^{n.s.}
pH-value	YOF	-0.788***
moisture	YOF	0.630***
temp	YOF	0.037 ^{n.s.}
precipitation sum	YOF	-0.954***
rainfall/runoff ratio	YOF	-0.828***

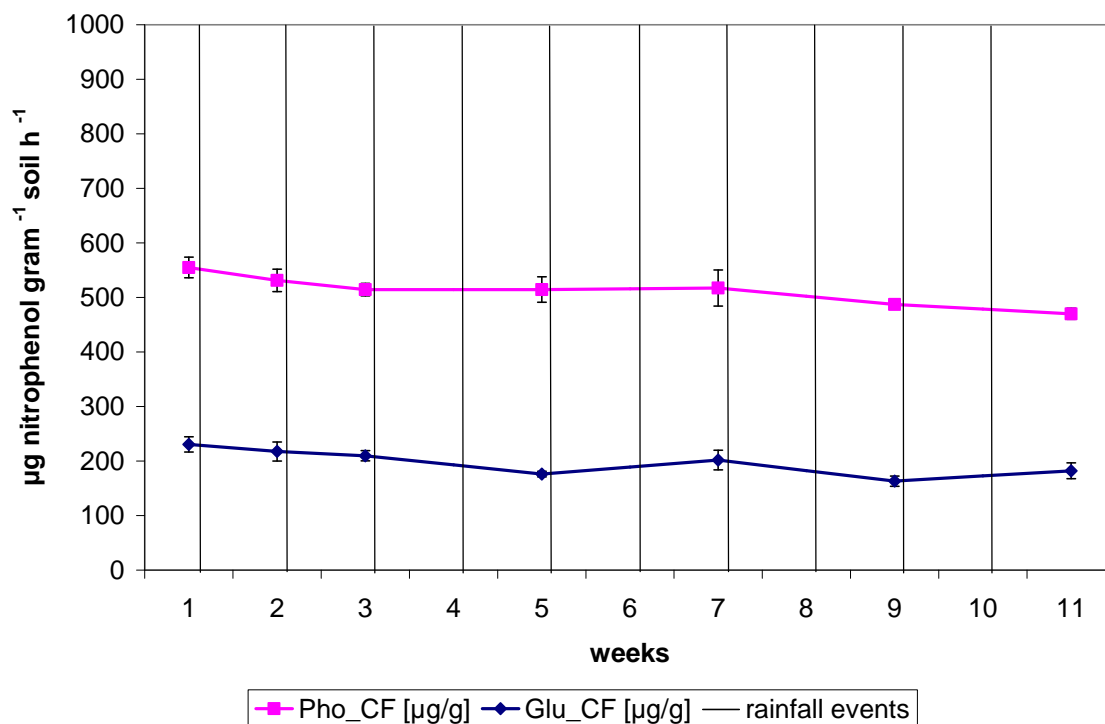
^a Level of significance: * P <0.05, ** P <0.01, *** P <0.001, n.s. not significant

^b Acid-phosphatase (Pho), β-glucosidase (Glu), organic carbon (Corg) content, microbial carbon (Cmic) content, Cmic/Corg ratio, nitrogen content, C/N ratio, pH-value, soil moisture content (moisture), soil temperature as seven day moving average (temp), precipitation sum and rainfall/runoff ratio

4.3.3 Conventional Farming soil

4.3.3.1 Enzyme activity

During the rainfall experiment the enzyme activity of acid-phosphatase ranged between 554 $\mu\text{g NP/g}\cdot\text{h}$ and 470 $\mu\text{g NP/g}\cdot\text{h}$ and showed a decreasing tendency until the last sampling. Furthermore the β -glucosidase activity ranged between 230 $\mu\text{g NP/g}\cdot\text{h}$ and 163 $\mu\text{g NP/g}\cdot\text{h}$ and showed as well as the acid-phosphatase a decreasing trend during the rainfall experiment (Fig. 66).



Error bars indicate the standard deviation between 6 replications

Fig. 66 Enzyme activity of acid-phosphatase (Pho) and β -glucosidase (Glu) at the CF soil during the rainfall experiment

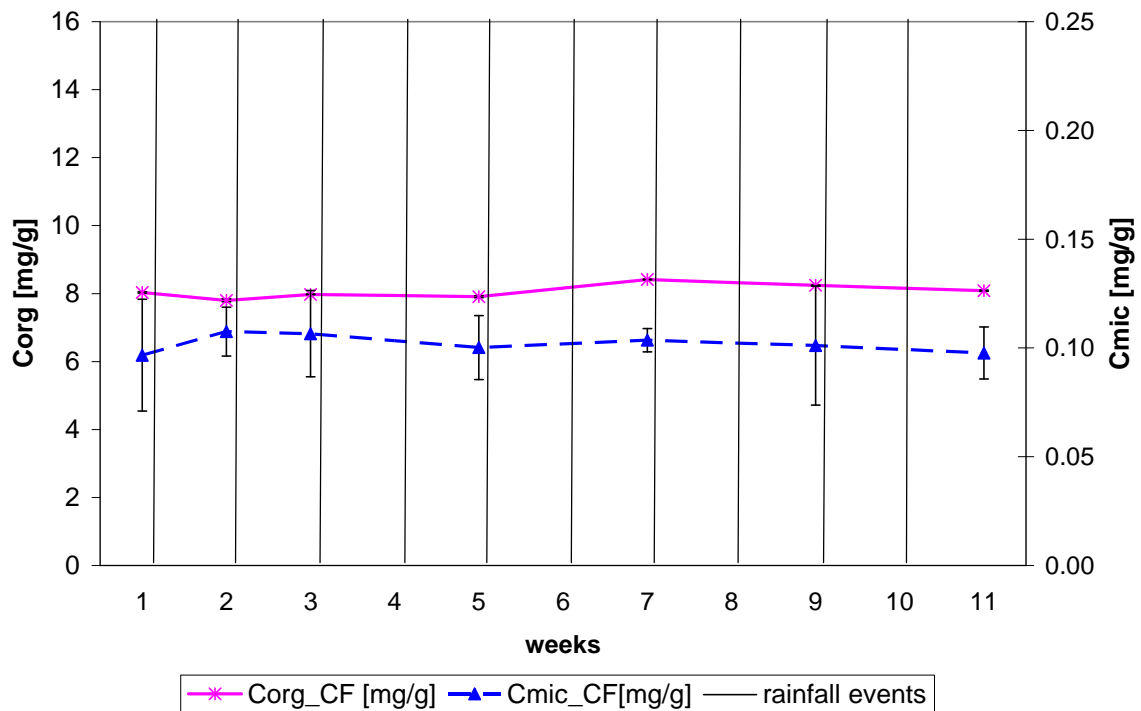
4.3.3.2 Carbon

Organic carbon (Corg)

The organic carbon content stayed during the whole rainfall experiment at a more or less constant level with changes between 7.8 mg/g and 8.4 mg/g (Fig. 67).

Microbial carbon (Cmic)

During the rainfall experiment the CF soil had microbial carbon contents between 0.097 mg/g and 0.107 mg/g. No increasing or decreasing tendency could be observed due to the error bars (Fig. 67).



Error bars indicate the standard deviation between 3 replications (error bars for Corg not visible)

Fig. 67 Organic carbon (Corg) content and microbial carbon (Cmic) at the CF soil during the rainfall experiment

Cmic/Corg ratio

In addition to the Cmic and Corg contents the Cmic/Corg ratio showed only weak dynamic changes between 1.2 % and 1.3 % (Fig. 67).

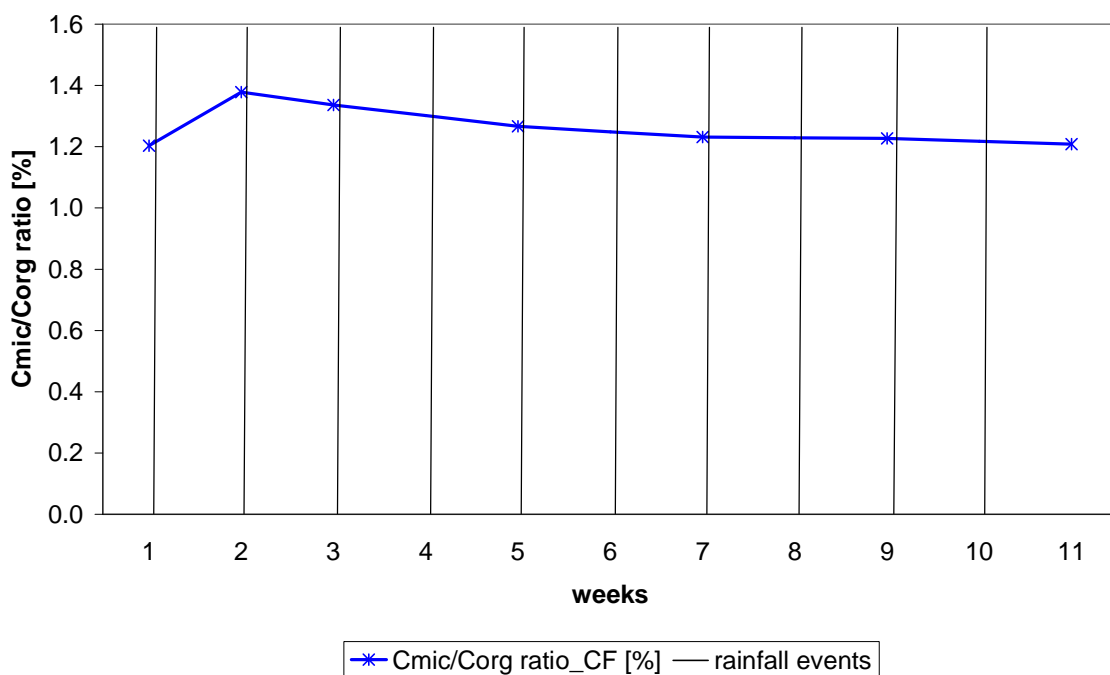
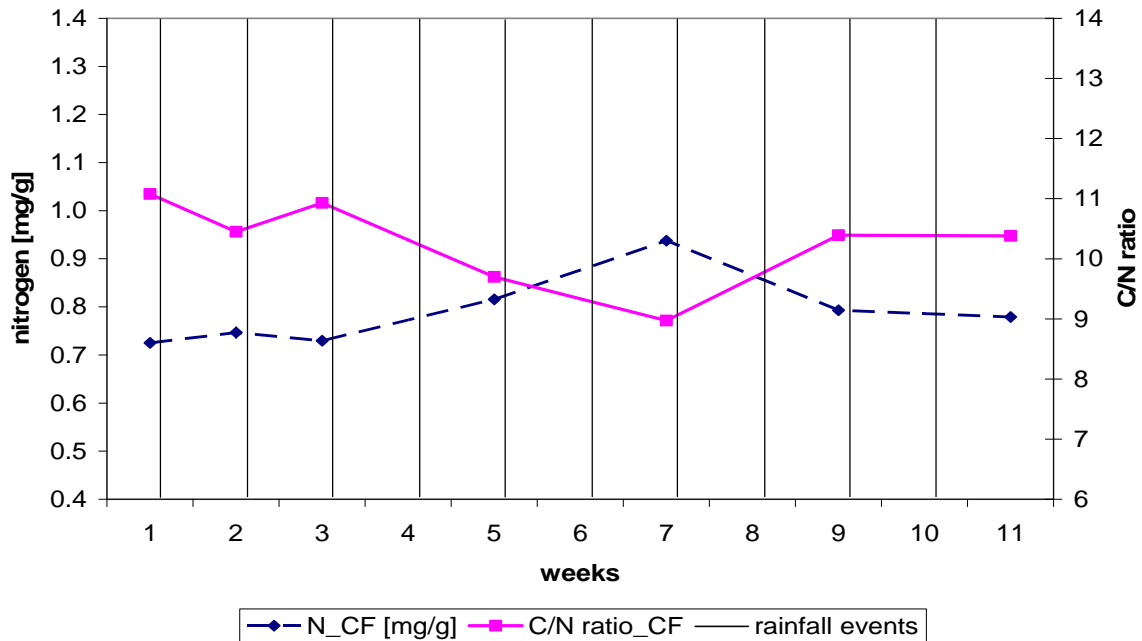


Fig. 68 Cmic/Corg ratio at the CF soil during the rainfall experiment

4.3.3.3 Nitrogen and C/N ratio

In the rainfall experiment the nitrogen content ranged between 0.73 mg/g and 0.94 mg/g with an increasing tendency until the seventh rainfall event and a subsequent decreasing tendency. Furthermore the calculated C/N ratio showed during the first 7 rainfall events a decreasing trend and increased after the seventh until the last rainfall event. The C/N ratio showed dynamic changes between 11.1 and 9.0 (Fig. 69).



Error bars indicate the standard deviation between 3 replications (not visible)

Fig. 69 Nitrogen content and C/N ratio at the CF soil during the rainfall experiment

4.3.3.4 pH-value

In the rainfall experiment the pH-value showed weak dynamic changes with the maximum value at pH 6.7 and a minimum value at pH 6.4 (Fig. 70).

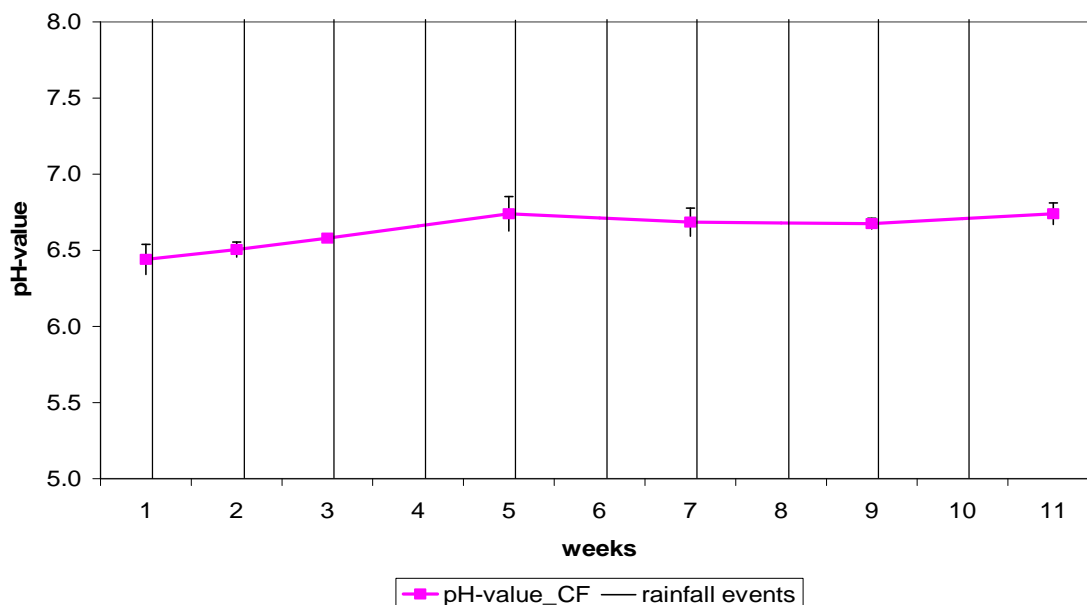


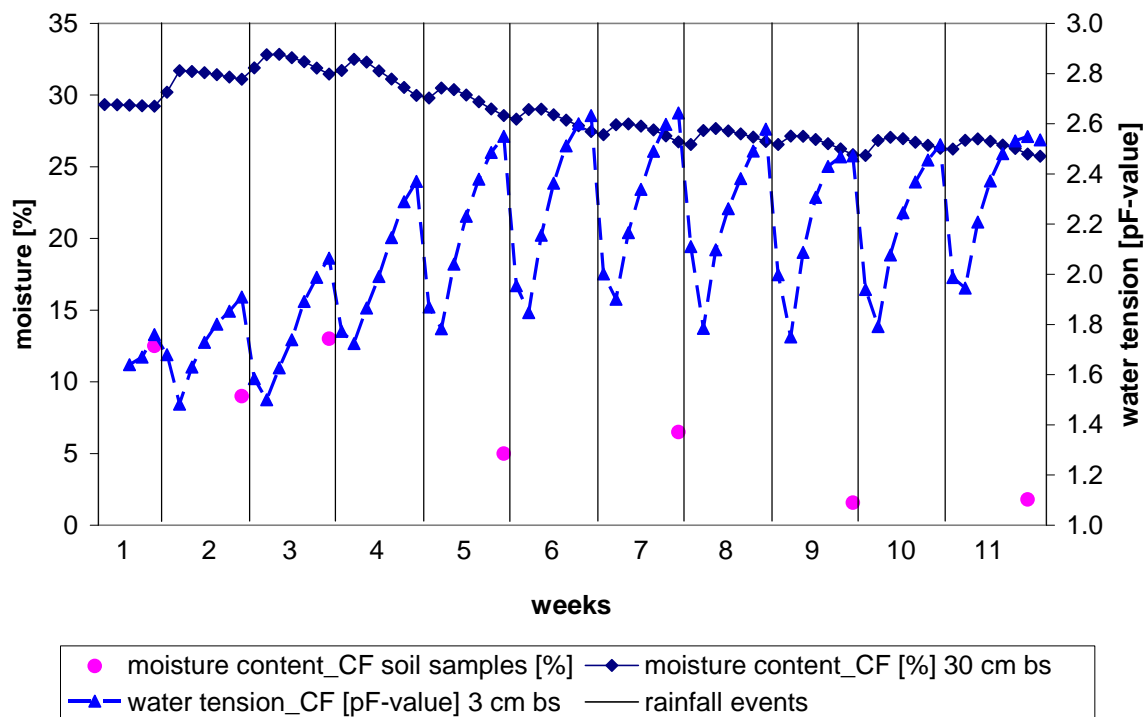
Fig. 70 pH-value at the CF soil during the rainfall experiment

4.3.3.5 Soil water

Soil moisture content

The soil moisture content in the soil samples of the upper 3 cm of the soil surface (taken for the biotic and abiotic analysis) changed between 13.0 % and 1.6 % with a decreasing trend during the at the last five sampling times (Fig. 71).

The continuous measured water content 30 cm below the soil surface was and expressed as mean of 24 hours during the laboratory experiment. Before the first rainfall event the soil moisture content was at a nearly constant level with more or less 29.3 % and increased subsequent to first and second rainfall event to 32.8 %. In general two days after the rainfall event the soil moisture content increased and decreased subsequent until the next rainfall event. Furthermore it could be observed that the water content 30 cm below the surface showed a decreasing tendency with increasing number of rainfall events (Fig. 71).



*taken from the upper 3 cm of the soil surface

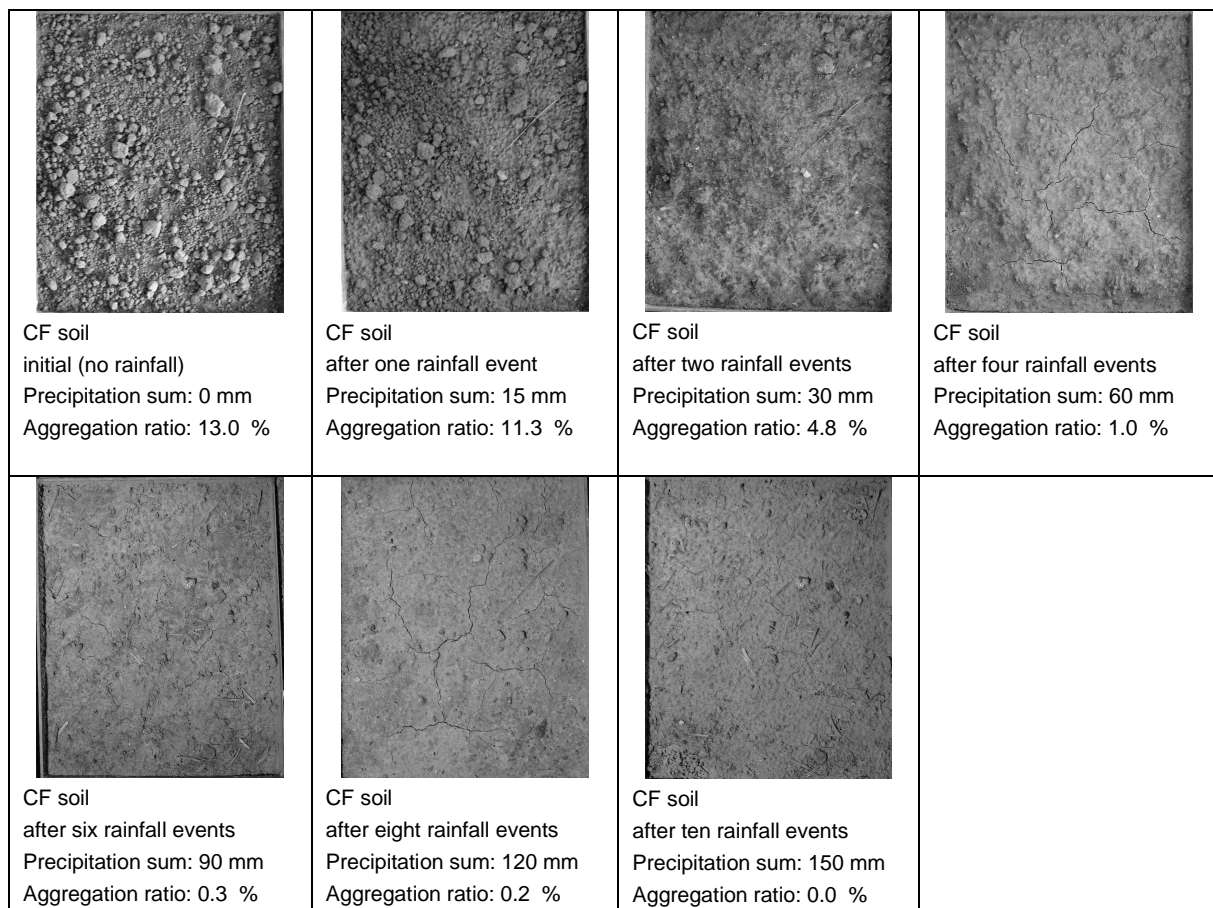
Fig. 71 Soil moisture content of the CF soil samples*, soil moisture content 30 cm below the soil surface (bs) as well as water tension 3 cm below the soil surface (bs) during the rainfall experiment

Matric potential

In the rainfall experiment the soil water tension 3 cm below the soil surface was measured continuously and shown as mean of 24 hours in Fig. 71. The water tension as expressed as pF-value ranged during the experiment between dry soil conditions (e.g. pF 2.64) and moist soil conditions (e.g. pF 1.48). In general the water tension decreased until 2 after the rainfall events and increased subsequently until the next rainfall event.

4.3.3.6 Soil surface roughness

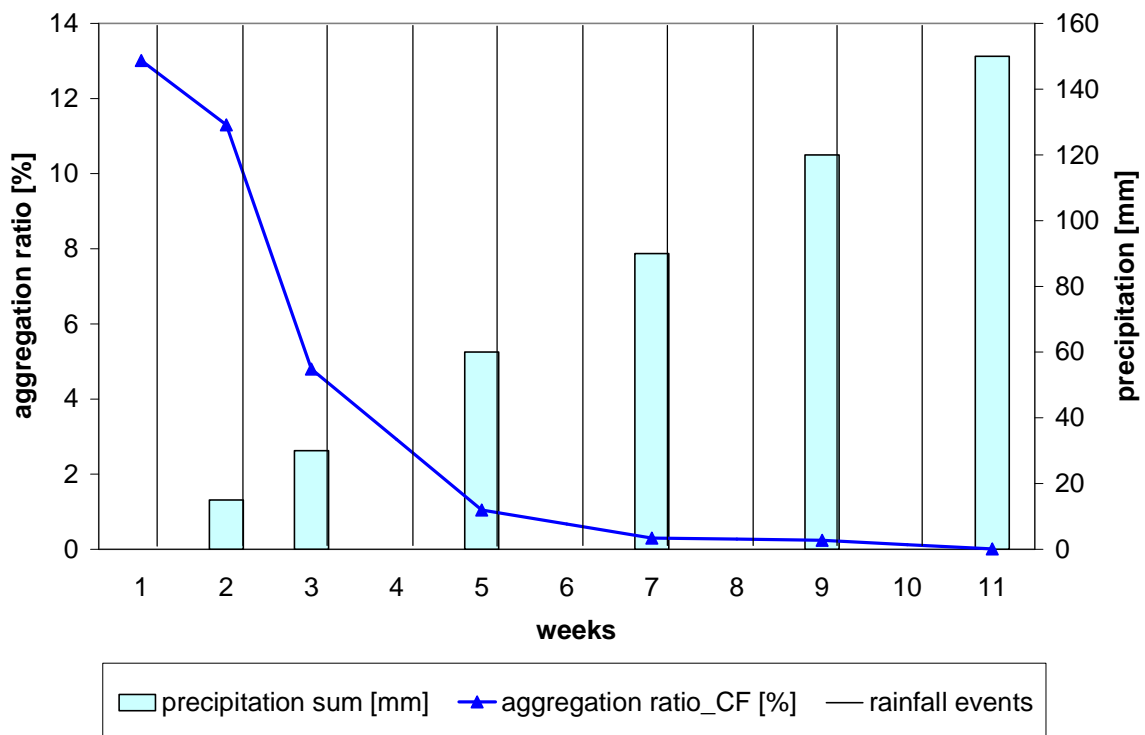
The initial aggregation ratio at the soil surface of the CF soil box was 13.0 %, decreased to 11.3 % after the first rainfall and to 4.8 % after the second rainfall. Subsequent the aggregation ratio declined with increasing number of rainfall events to 0.0 % after the tenth rainfall event. In the visual assessment it could be revealed that after 15 mm rainfall the soil surface showed a weak but visible soil surface sealing behavior. After 30 mm precipitation the soil surface was totally sealed and crusted until the last rainfall event (Fig. 72).



* soil box 1

Fig. 72 Image sequence of the inner core unit at the CF soil surface* during the rainfall simulation

Furthermore the aggregation ratio at the CF soil surface in relation to the rainfall sum is shown in Fig. 73.

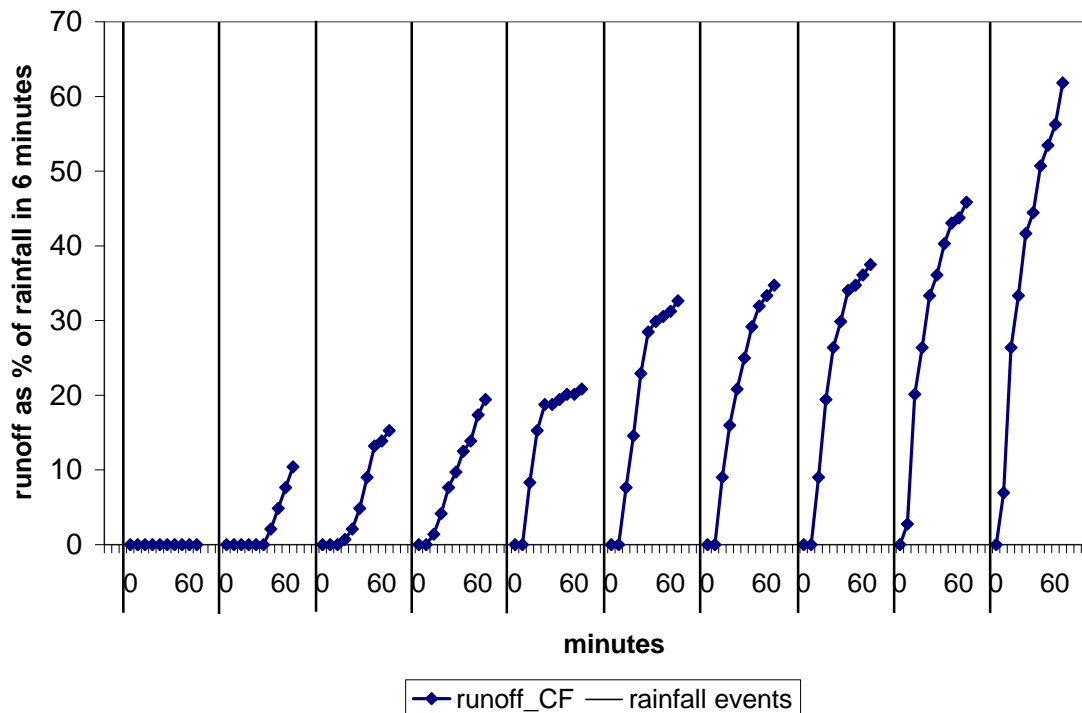


*soil box 1

Fig. 73 Precipitation sum as well as aggregation ratio at the CF soil surface* during the rainfall experiment

4.3.3.7 Runoff

The runoff at the conventional farming soil during the rainfall experiment started at the second rainfall event among 36 and 42 minutes of rainfall and reached a runoff rate of 10.4 % of rainfall during the 54 to 60 minutes interval. At the third rainfall event the runoff started in the 18 to 24 minute interval and beginning at the fourth to the eighth rainfall event between 12 and 18 minutes. At the ninth and tenth rainfall event the runoff started in the 6 to 12 minute interval. At the 54 to 60 minute interval the runoff was 32.6 % of rainfall in the sixth rainfall event and 61.8 % of rainfall in the tenth rainfall event, respectively (Fig. 74).



The runoff was measured in 6 minutes intervals during each 60 minutes rainfall event. After each rainfall event the soil surface was dried for duration of six days. At the seventh day the next rainfall event was conducted.

Fig. 74 Runoff during the rainfall events at the CF soil surface (6 % slope) as % of rainfall fallen in 6 minutes

4.3.3.8 Correlation statistics

In the regression analysis the enzyme activities of acid-phosphatase and β -glucosidase showed positive and significant correlation to the aggregation ratio and to the soil moisture content. Negative significant correlations were found to the pH value, precipitation sum and to the rainfall/runoff ratio. No significant correlation could be found between the enzyme activities and the Corg, Cmic and nitrogen content as well as to the C/N ratio and the soil temperature as seven day moving average (Table 15).

Furthermore the aggregation ratio was tested against the variables shown in Table 16. Significant correlations were found to the enzyme activities, the Cmic/Corg ratio, C/N ratio as well as to the soil moisture content in the soil samples. Negative significant correlations were found between the aggregation ratio and Corg, nitrogen, pH-value, total rainfall and to the rainfall/runoff ratio. Furthermore no significant correlation was found to Cmic content and to the soil temperature as seven day moving average 3 cm below the soil surface.

Table 15 Correlation coefficients (R)^a between enzyme activities^b and biotic and abiotic parameters^c at the CF soil during the rainfall experiment

rainfall experiment			
variable	site	acid-phosphatase	β-glucosidase
aggregation ratio	CF	0.820***	0.825***
Corg	CF	-0.304 ^{n.s.}	-0.299 ^{n.s.}
Cmic	CF	0.137 ^{n.s.}	0.217 ^{n.s.}
Cmic/Corg ratio	CF	0.254 ^{n.s.}	0.315 ^{n.s.}
nitrogen	CF	-0.207 ^{n.s.}	-0.336 ^{n.s.}
C/N ratio	CF	0.197 ^{n.s.}	0.370*
pH-value	CF	-0.807***	-0.860***
moisture	CF	0.810***	0.882***
temp	CF	0.083 ^{n.s.}	0.027 ^{n.s.}
precipitation sum	CF	-0.927***	-0.803***
rainfall/runoff ratio	CF	-0.688***	-0.910***

^a Level of significance: * P <0.05, ** P <0.01, *** P <0.001, n.s. not significant

^b Acid-phosphatase, β-glucosidase

^c Aggregation ratio, organic carbon (Corg) content, microbial carbon (Cmic) content, Cmic/Corg ratio, nitrogen content, C/N ratio, pH-value, soil moisture content (moisture), soil temperature as seven day moving average (temp), precipitation sum and rainfall/runoff ratio

Table 16 Correlation coefficients (R)^a between the aggregation ratio and biotic and abiotic parameters^b at the CF site during the rainfall experiment

rainfall experiment			
variable	site	aggregation ratio	
Pho	CF	0.820***	
Glu	CF	0.852***	
Corg	CF	-0.559**	
Cmic	CF	0.117 ^{n.s.}	
Cmic/Corg	CF	0.363*	
nitrogen	CF	-0.626**	
C/N ratio	CF	0.606***	
pH-value	CF	-0.960***	
moisture	CF	0.756***	
temp	CF	-0.276 ^{n.s.}	
precipitation sum	CF	-0.857***	
rainfall/runoff ratio	CF	-0.887***	

^a Level of significance: * P <0.05, ** P <0.01, *** P <0.001, n.s. not significant

^b Acid-phosphatase (Pho), β-glucosidase (Glu), organic carbon (Corg) content, microbial carbon (Cmic) content, Cmic/Corg ratio, nitrogen content, C/N ratio, pH-value, soil moisture content (moisture), soil temperature as seven day moving average (temp), precipitation sum and rainfall/runoff ratio

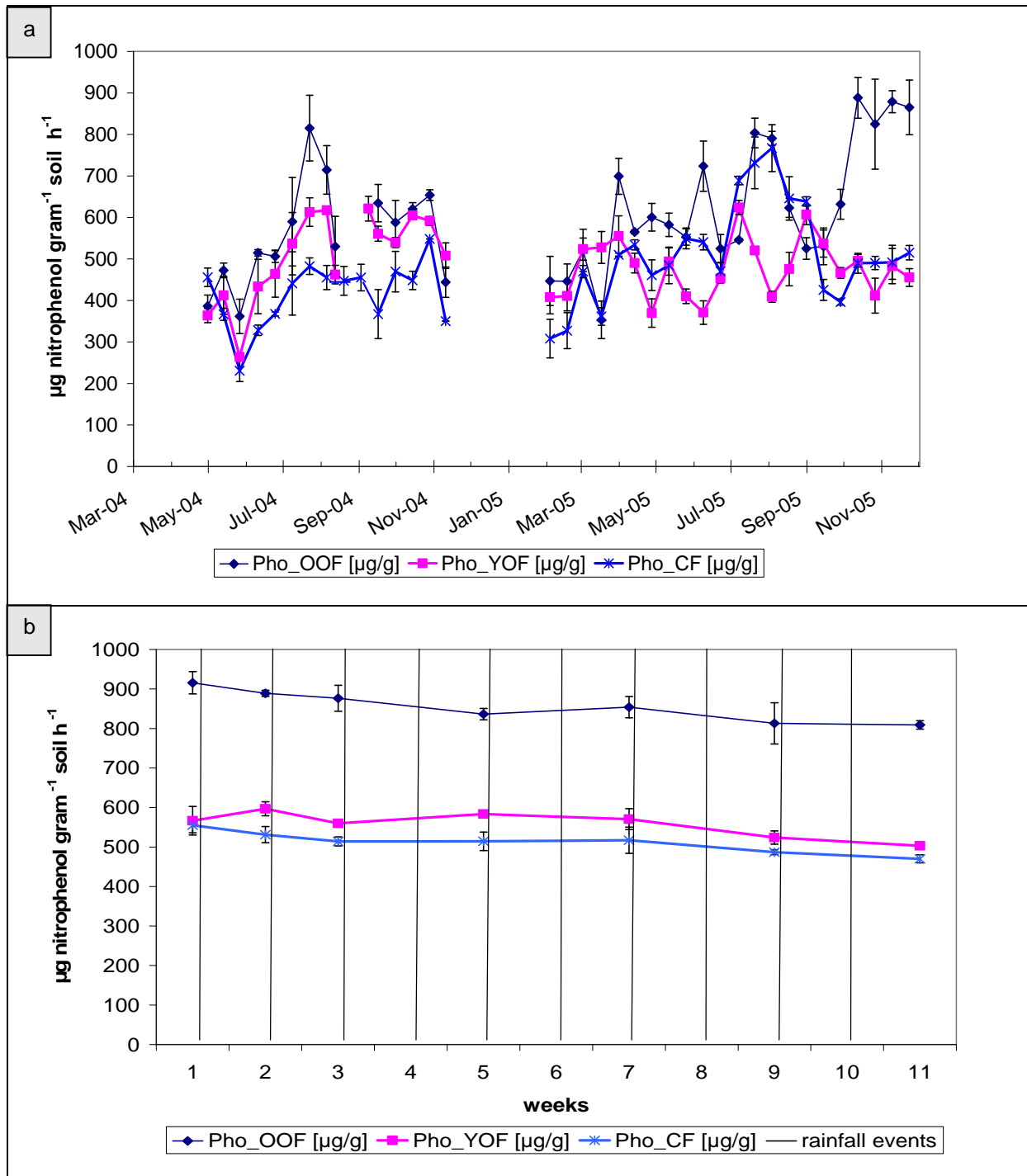
5 Discussion

In this chapter the effects of the agricultural management system on the enzyme activities and measured factors such as organic carbon, microbial carbon, C_{mic}/C_{org} ratio, nitrogen, C/N ratio, pH-value as well as temperature and soil moisture content are described. In addition these factors are discussed if they were significantly influenced from the management systems as well as if they have the potential to affect the enzyme activities and their dynamic changes. Furthermore the soil surface behavior during the field experiment as well as at the rainfall experiment is considered. Over and above in the rainfall experiment the runoff pattern in combination with the infiltration rate, the changed water matric potential as well as the water content underneath the soil surface are shown and the effects discussed.

5.1 Influence of management systems on soil biotic and abiotic factors

5.1.1 Enzyme activity of acid-phosphatase and β -glucosidase

The rhizosphere is generally known to be a zone of increased microbial activity as well as of enlarged enzyme activity (Bandick and Dick, 1999). In the accomplished experiments the enzyme activity of acid-phosphatase in the upper 3 cm of the soil surface ranged (at the three sites) between 230 $\mu\text{g NP/g}^*\text{h}$ and 888 $\mu\text{g NP/g}^*\text{h}$ in the field experiment and between 470 $\mu\text{g NP/g}^*\text{h}$ and 916 $\mu\text{g NP/g}^*\text{h}$ in the laboratory rainfall experiment (Fig. 75). Klose and Tabatabai (2002a, b) found in this regard enzyme activities in the summer (two observations) and in the fall (two observations) of 226 $\mu\text{g NP/g}^*\text{h}$ up to 641 $\mu\text{g NP/g}^*\text{h}$ in German topsoil (0 -10 cm). Also Ekenler and Tabatabai (2003a) found at one sampling during the summer vegetation period in the top 5 cm of an Iowa (USA) soil activities of 323 $\mu\text{g NP/g}^*\text{h}$ up to 386 $\mu\text{g NP/g}^*\text{h}$ for acid-phosphatase. The lower enzymes activities were explained from several other researches (e.g. Bergstrom et al., 1998; Curci et al., 1997; Doran, 1980; Dick, 1984; Dick et al., 1988; Ekenler and Tabatabai, 2003a; Landgraf and Klose, 2002; Tabatabai, 1994) who in general found lower enzyme activities with increasing soil depth.



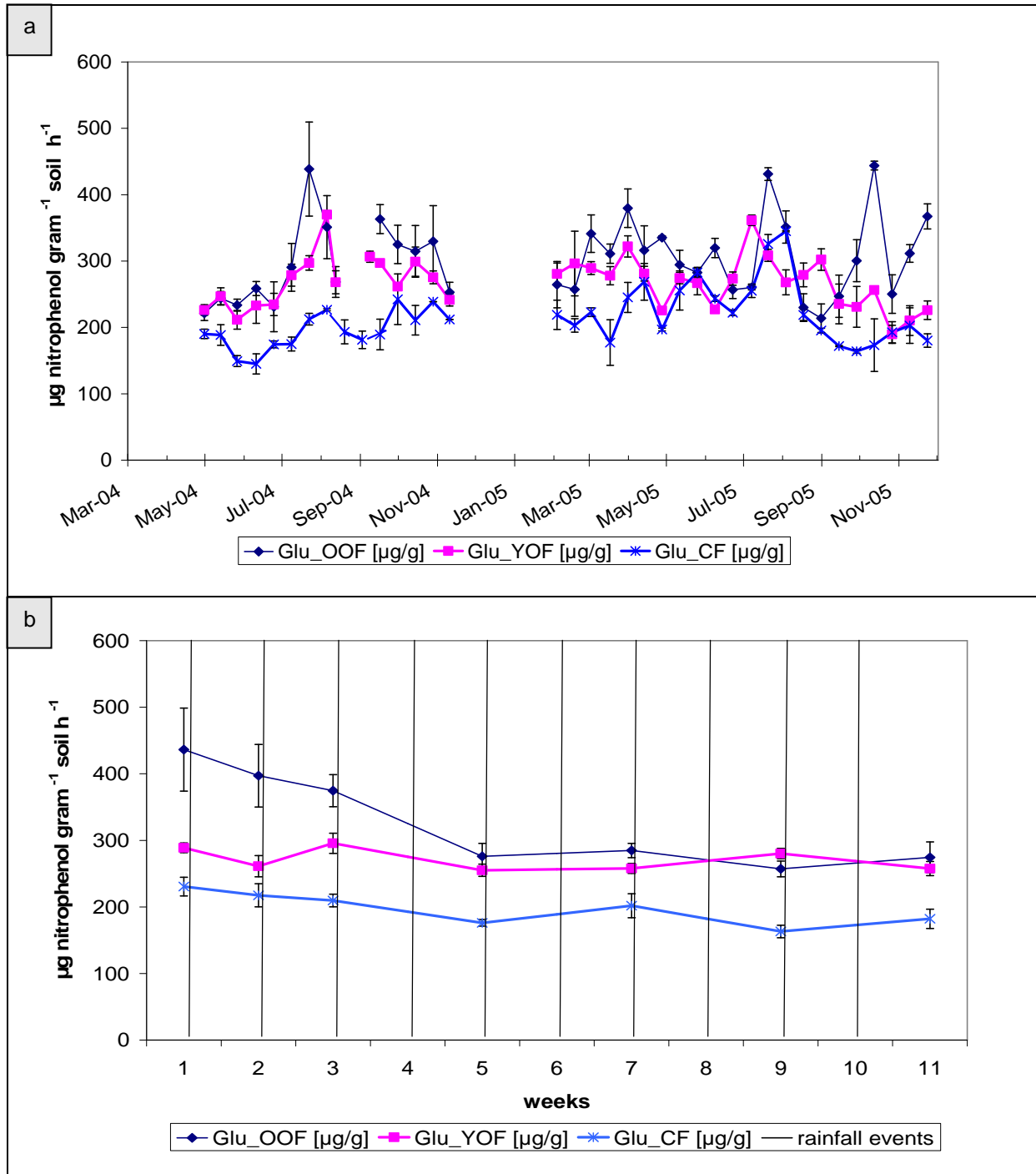
The enzyme activity of acid-phosphatase was at the first sampling in the rainfall experiment at the same level as at the soil sampling on 14-October-2005 in the field experiment

Error bars indicate the standard deviation between 9 replications in the field and 6 replications in the rainfall experiment

Fig. 75 Enzyme activity of acid-phosphatase (Pho) at the OOF, YOF and CF sites in the field (a) and laboratory rainfall experiment (b)

The β -glucosidase activity in the top 3 cm of the OOF, YOF and CF soil ranged from 145 $\mu\text{g NP/g}\cdot\text{h}$ to 443 $\mu\text{g NP/g}\cdot\text{h}$ in the field experiment and between 163 $\mu\text{g NP/g}\cdot\text{h}$ and 397 $\mu\text{g NP/g}\cdot\text{h}$ in the laboratory rainfall experiment (Fig. 75). Concerning this matter Acosta-Martinez et al. (1999) found in the upper 1.3 cm of a silty clay loam (Indiana, USA) in two

summer and one fall sampling activities between 494 $\mu\text{g NP/g}\cdot\text{h}$ and 613 $\mu\text{g NP/g}\cdot\text{h}$. Furthermore Mendes et al. (1999) measured in the upper 20 cm of an Oregon soil (USA) in June and September (one sampling per month) activities between 100 $\mu\text{g NP/g}\cdot\text{h}$ and 120 $\mu\text{g NP/g}\cdot\text{h}$. Landgraf and Klose (2002) detected enzyme activities on one date in May between 76 $\mu\text{g NP/g}\cdot\text{h}$ and 89 $\mu\text{g NP/g}\cdot\text{h}$ in the top 5 cm of a German sandy soil.



The enzyme activity of β -glucosidase was at the first sampling in the rainfall experiment at the same level as at the soil sampling on 14-October-2005 in the field experiment

Error bars indicate the standard deviation between 9 replications in the field and 6 replications in the rainfall experiment

Fig. 76 Enzyme activity of β -glucosidase (Glu) at the OOF, YOF and CF sites in the field (a) and laboratory rainfall experiment (b)

In general the enzyme activities of acid-phosphatase and β -glucosidase showed during two years of continuous measurement at the field experiment more dynamic effects than during the rainfall experiment. Schneider et al. (2001) found in central Spain as well high dynamic changes between seasons, while Bandick and Dick (1999) and Dick et al. (1988) observed in the North American region only weak seasonality changes in acid-phosphatase and β -glucosidase activity. In Fig. 77 the Box-Whisker plot analysis is shown.

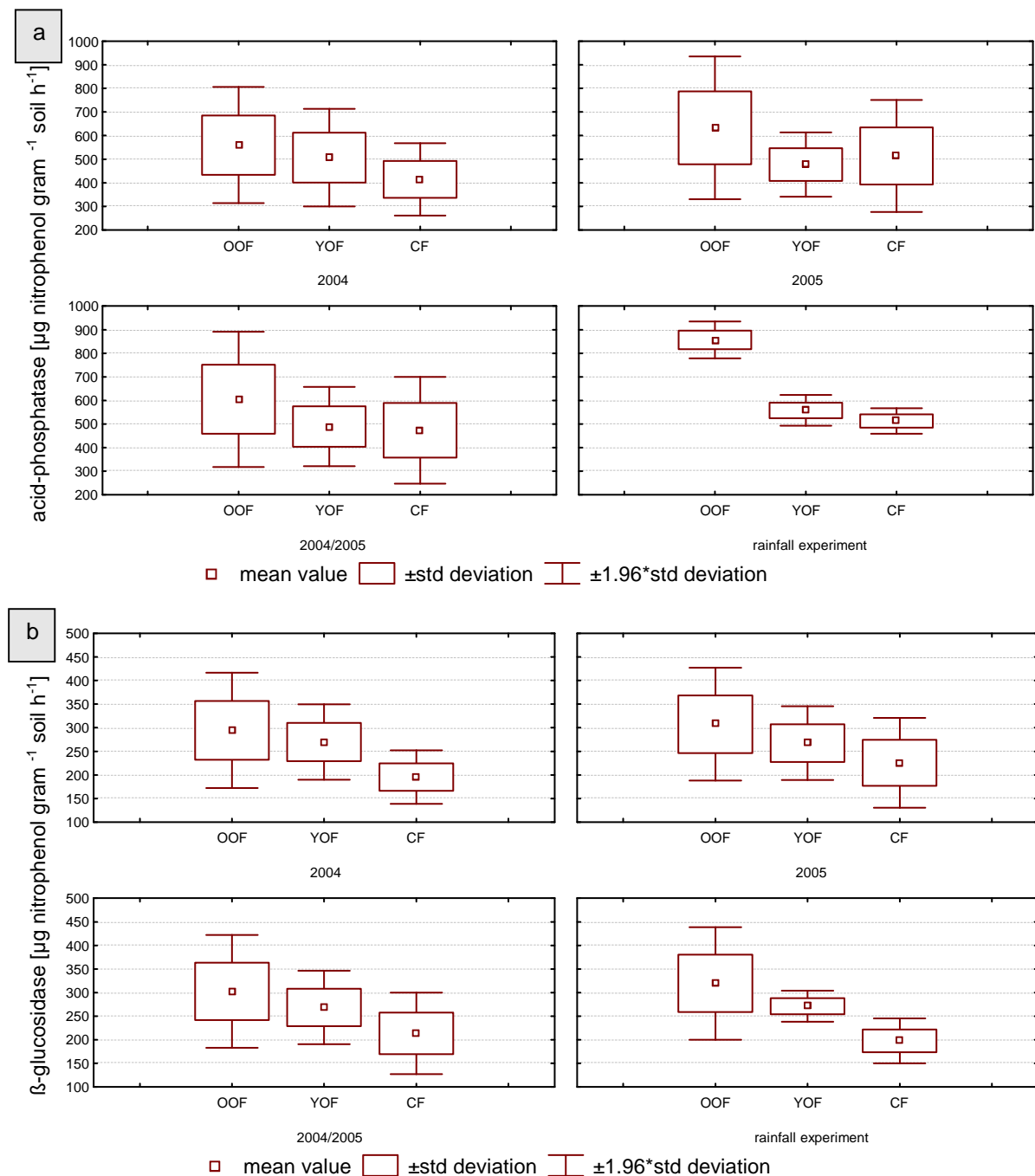


Fig. 77 Box-Whisker-Plot design for acid-phosphatase (a) and β -glucosidase (b) at the OOF, YOF and CF site in the field (2004, 2005 as well as considered together 2004/2005) and rainfall experiment

In general the mean values of acid-phosphatase and β -glucosidase were at the OOF site higher than at the YOF site. Both organically managed sites (OOF, YOF) showed higher mean square values for acid-phosphatase (with an exception for 2005) and β -glucosidase than at the CF site. Therefore the Young Organic Farming (recently established) system can be understood as interstage between the Conventionally Farming system and the well established Old Organic Farming system. This result was in accordance with other researches who found that acid-phosphatase and β -glucosidase activity can differentiate between soil management systems (Bandick and Dick, 1999; Ndiaye et al., 2000). Therefore Mäder et al. (2002) found higher acid-phosphatase activities in organic farming systems than in conventional farming systems of a loess soil in Switzerland. Kahle et al. (2004) found as well higher β -glucosidase and phosphatase activities under organic condition than under conventional conditions. The higher enzyme activity of acid-phosphatase and β -glucosidase at the organic farming sites (e.g. with cover crops) compared to the conventional farming site (e.g. without cover crops) were be explained by findings of Mäder et al. (2002) who found increased root length in organically farming systems compared to conventionally systems. George et al. (2002), Schneider et al. (2001) and Schinner and Sonnleitner (1996a) showed that the acid-phosphatase activity in the rhizosphere is in general affected by plant roots. In addition Tabatabai (1994) revealed that β -glucosidase activity increased as a result of enhanced plant root growth. Furthermore Bandick and Dick (1999) showed that winter cover crops increase the enzyme activity, probably due to the increased concentration of organic C compounds (Alvarez et al., 1995). The ANOVA results are shown in Table 17.

Table 17 One factor analysis of variance (ANOVA) for acid-phosphatase (a) and β -glucosidase (b) activity in 2004, 2005, 2004/2005 and in the rainfall experiment

a	Pho-2004	OOF	YOF	Pho-2005	OOF	YOF
	YOF	0.1762		YOF	0.0000	
	CF	0.0000	0.0000	CF	0.0007	0.2941
	Pho-04/05	OOF	YOF	Pho-rain	OOF	YOF
	YOF	0.0000		YOF	0.0000	
	CF	0.0000	0.5695	CF	0.0000	0.0231
b	Glu-2004	OOF	YOF	Glu-2005	OOF	YOF
	YOF	0.1762		YOF	0.0074	
	CF	0.0000	0.0000	CF	0.0000	0.0078
	Glu-04/05	OOF	YOF	Glu-rain	OOF	YOF
	YOF	0.0036		YOF	0.0320	
	CF	0.0000	0.0000	CF	0.0000	0.0024

Bold numbers indicate significant differences

The Box-Whisker-Plots as well as the ANOVA analysis exhibited for 2004 that the acid-phosphatase and β -glucosidase activity at organic farming sites were not significantly different among themselves but were significantly different to the acid-phosphatase and β -glucosidase activity at the conventional farming site. In 2005 and for the whole experimental

field period (2004 and 2005 combined) the enzyme activity was significantly different between the Old Organic Farming site, the Young Organic Farming site and the Conventional Farming site. These findings were in accordance with Green et al. (2006) who showed that acid-phosphatase activity was sensitive to the soil management in the surface depth of 0 - 5 cm as well as to Deng and Tabatabai (1997) who revealed that tillage and residue management practices have similar effects on the activities of the enzymes involved in C and P cycling in soils.

To analyze if the dynamic changes of acid-phosphatase and β -glucosidase at each site were significantly correlated, the SAS linear regression method was conducted. The results showed a high positive correlation between both enzyme activities at the OOF, YOF and CF sites in the field experiment (Table 18). The correlation coefficients for the laboratory rainfall experiment are not shown, because the dynamic changes for acid-phosphatase and β -glucosidase were too weak to calculate valid correlations.

Table 18 Correlation coefficients (R)^a between acid-phosphatase and β -glucosidase in the field experiment 2004, 2005 as well as for 2004/2005

site	year	enzyme	Glu		
			2004	2005	2004/2005
OOF	2004	pH	0.940***		
	2005			0.571**	
	2004/2005				0.693***
YOF	2004		0.829***		
	2005			0.614**	
	2004/2005				0.704***
CF	2004		0.737***		
	2005			0.680***	
	2004/2005				0.733***

^a Level of significance: * P <0.05, ** P <0.01, *** P <0.001, n.s. not significant

The significant correlations between the enzymes at each site showed that the management system in general influenced the acid-phosphatase and β -glucosidase activity in the same way. Other researchers as well found positive significant correlations (e.g. range of R=0.38*, R=0.58***, R=0.81**) between acid-phosphatase (Acosta-Martinez et al., 2004; Green, 2006) and β -glucosidase (Acosta-Martinez et al., 2004). Deng and Tabatabai (1997) revealed that tillage and residue management practices have similar effects on the activities of enzymes which are involved in the C and P cycles in soils.

5.1.2 Influence of the soil texture on the enzyme activity

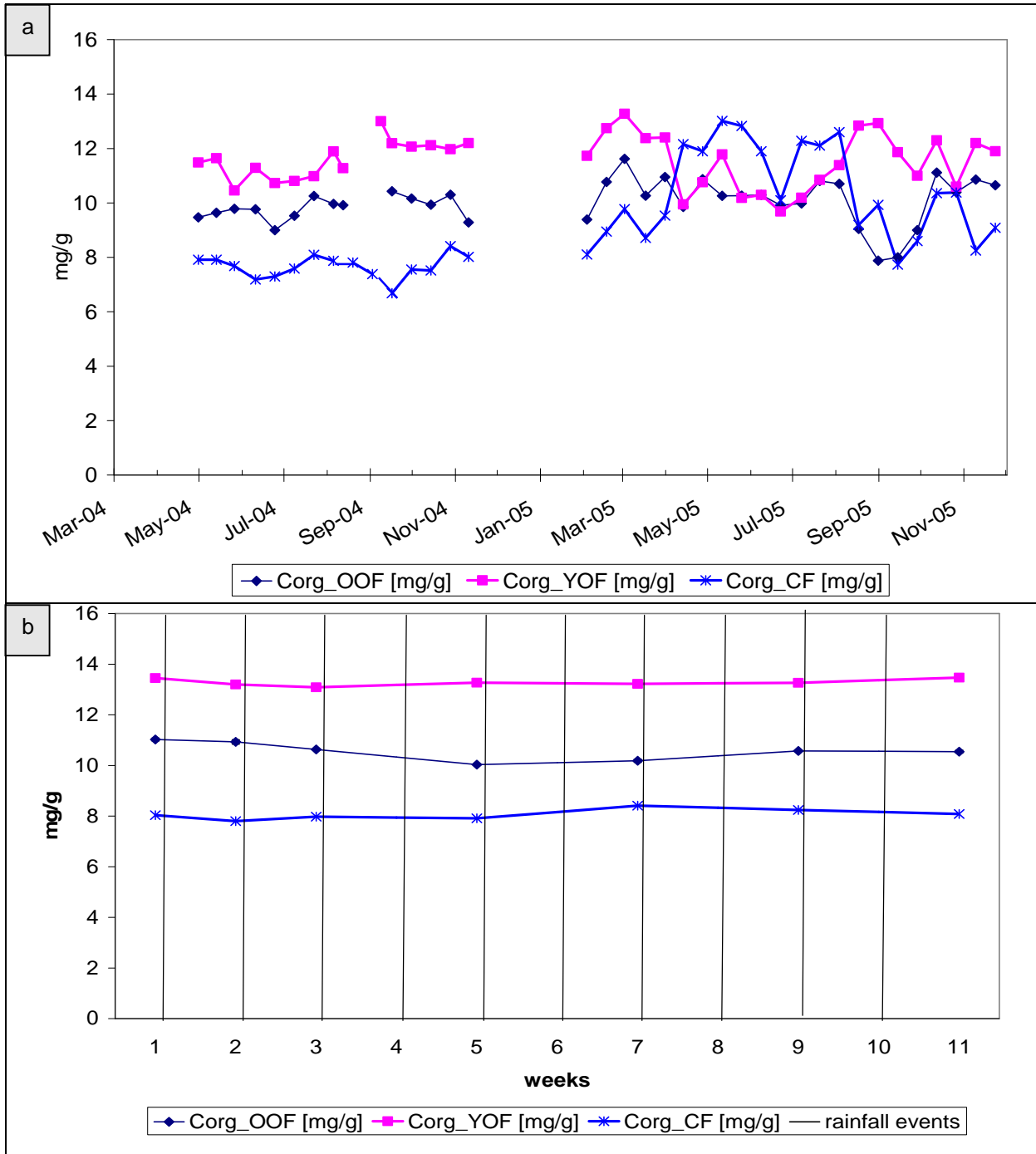
A substantial fraction of extracellular (abiotic) enzyme activity such as acid-phosphatase and β -glucosidase can be stabilized on clay and/or humus colloids and can maintain their activity for extended periods of time (Acosta-Martinez et al., 2004; Beck and Beck, 2000; Knight and Dick, 2004; Koroljova-Skorobogatko et al., 1998; Nannipieri et al., 1996; Rao et al., 1996). Knight and Dick (2004) also stated that the stabilization of β -glucosidase in the soil matrix is controlled by chemical complexation/sorption processes, the chemical character of organic matter inputs and physical protection mechanisms. In addition Tarafdar and Marschner (1994) revealed that high clay contents resulted in an increased phosphatase activity in the root surface area. Ladd et al. (1996) and Sparling (1997) showed that in general greater microbial biomass C, and therefore enzyme activities can rather be sustained in finer textured soils, compared to coarser-textured soils under similar land use. The soil enzymes, if stabilized are resistant against denaturing by heat and other stresses (Burns, 1982; Deng and Tabatabai, 1994; Miller and Dick, 1995b; Nannipieri et al., 1988; 1996; 2002; Tabatabai, 1994), because they are decoupled from microbial regulations (Burns, 1982). Furthermore the clay content stabilizes organic carbon against oxidation (Golchin et al., 1994; Ladd et al., 1993) because the adsorption of organic molecules onto clay mineral surfaces provides mechanism of stabilization of organic matter against microbial attack (Baldock and Nelson, 2000; Ladd et al., 1996). The clay contents ranged between 10.1 % at the OOF site and 14.6 % at the YOF site. Due to the small differences between the soil textures the enzyme activities were presumably not soil related.

5.1.3 Organic carbon

The soil organic carbon is responsible for soil health, productivity and soil quality (Campbell et al., 1992; Dodor and Tabatabai, 2005). Therefore many authors (e.g. Arshad et al., 1990; Bescansa et al., 2006; Rasmussen and Collins, 1991; Zhang et al., 2006) publicized that management practices such as tillage operations, crop residue management and fertilizer applications can result in changes in soil organic carbon levels. The importance of organic matter on soil structure is well recognized (e.g. Chaney and Swift, 1984; Oades, 1984; Pagliai et al., 2004) because surface organic matter is essential to soil aggregation, erosion control, water infiltration and is associated with better plant nutrition (Franzluebbers, 2002a; Moreno et al., 2006; Wander and Yang, 2000). Soil organic matter also plays an important role for enzyme activity (Anderson and Domsch, 1978; Deng and Tabatabai, 1997; Dick, 1984; Klose et al., 2003; Schinner and Sonnleitner, 1996b) in protecting soil enzymes since they become immobilized in a three dimensional network of clay and humus complexes (Tabatabai, 1994; McLaren, 1975). In addition Tarafdar and Marschner (1994) showed that high organic matter contents resulted in an increased production of phosphatases of plant origin due to an

increase in total root surface area. Busto and Perez-Mateos (1995) promoted this hypothesis and showed that as much as 50 % of the total β -glucosidase activity of the soil was bounded to humic compounds.

In Fig. 78 the organic carbon content at the Conventional Farming site (CF), Young Organic Farming site (YOF) and Old Organic Farming (OOF) site in 2004 and 2005 at the field experiment as well as at the rainfall experiment is shown. Due to the high measure accuracy of Corg the error bars are not visible in the figure.



Error bars indicate the standard deviation between 3 replications (not visible)

Fig. 78 Organic carbon (Corg) content at the OOF, YOF and CF sites in the field (a) and laboratory rainfall experiment (b)

In the field experiment the Corg content 2004/2005 ranged at the organically managed soils (OOF, YOF) between 7.9 mg/g and 13.3 mg/g and at the conventionally managed site (CF) between 6.7 mg/g and 13.0 mg/g. Contrary to the field experiment the organic carbon content in the laboratory rainfall experiment showed no remarkable changes during the whole period. The dynamic pattern in this occurrence during the field experiment was not expected because Green et al. (2006) and Haynes (1999) revealed that the accumulation of soil organic carbon in the soil is no rapid process. Although Arshad et al. (1990) emphasized that management practices such as tillage, crop residue management, fertilizer applications and land use can result in large dynamic changes in soil organic carbon levels. Furthermore Sarah (2006) stated that the organic carbon content varies in the short term (months or years) because of fluctuations in weather conditions between seasons and in between years.

To show any differences of the Corg content at the three sites the Box-Whisker-Plot analysis was carried out (Fig.79).

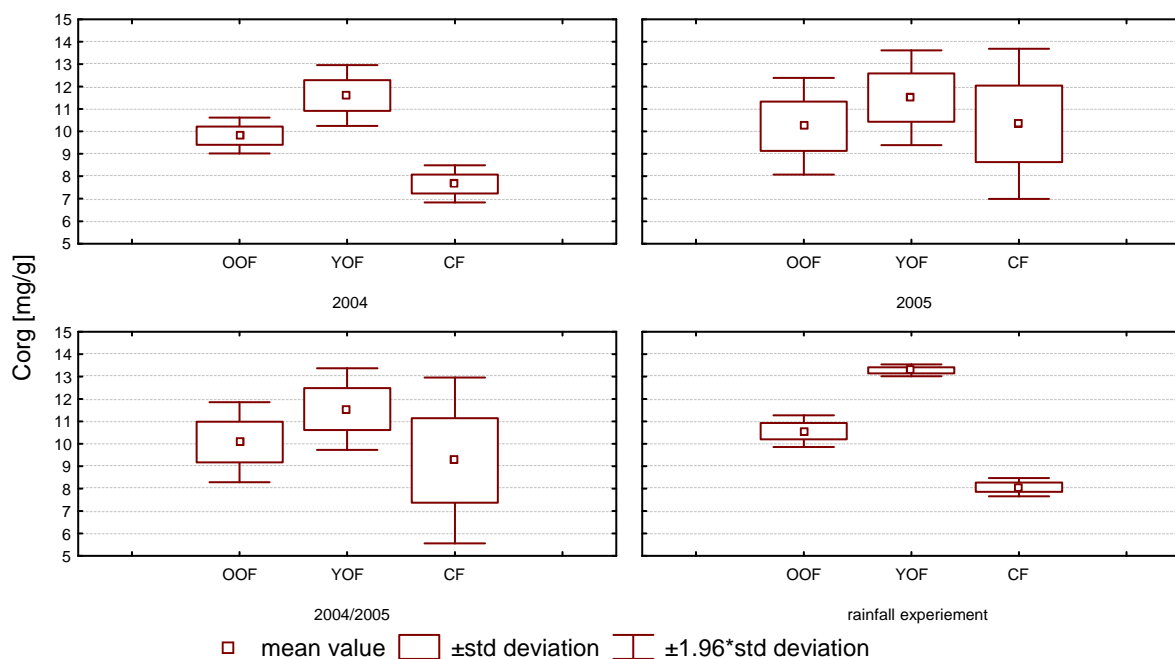


Fig. 79 Box-Whisker-Plot design for organic carbon content at the OOF, YOF and CF site in the field (2004, 2005 as well as considered together 2004/2005) and rainfall experiment

The mean organic carbon content in the field experiment 2004/2005 was at the Old Organic Farming site 10.00 mg/g, at the Young Organic Farming site 11.55 mg/g and at the Conventional Farming site 9.16 mg/g. These findings were in accordance with results from Sehy et al. (2000) who found organic carbon contents of 8.9 mg/g in an organically managed soil and 6.8 mg/g in a conventionally managed soil. In addition Schachtschabel et al. (2002) found organic carbon contents between 11.4 mg/g and 12.0 mg/g in farmed soils and Hoffmann et al. (2006) assessed 9.9 mg/g up to 12.1 mg/g in fertilized soils and

approximately 8.2 mg/g in unfertilized soils. Furthermore Körschens (2004) found that the Corg content for an optimum fertilized sandy soil is around 11 mg/g and on loess black soil approximately 51 mg/g.

The mean of the organic carbon content in the field experiment 2004/2005 was 24.8 % higher at the YOF site and 8.9 % higher at the OOF site than at the CF site. These data were in accordance with data received from the rainfall experiment where the organic carbon content at the YOF site was 63.9 % and at the OOF site 29.5 % higher than at the CF site. Supporting this matter Arshad et al. (1990) and Dolan et al. (2006) found a 26 % to 30 % increased soil organic carbon in the soil surface of no tillage than under moldboard tillage treatments. Deneff et al. (2004) analyzed conventional and no tillage sites with different time of conversion from conventional to no tillage. He found greater organic carbon levels in no tillage than under conventional tillage but stated also that differences in organic carbon were not only a result of time of conversion from conventional to no tillage management. The ANOVA analysis (Table 19) revealed that in general the Corg content was significantly influenced from the Old and Young Organic management system as well as from the conventional management.

Table 19 One factor analysis of variance (ANOVA) of organic carbon content and management system for 2004, 2005, 2004/2005 in the field and rainfall experiment

<table border="1"> <thead> <tr> <th>Corg-2004</th> <th>OOF</th> <th>YOF</th> </tr> </thead> <tbody> <tr> <td>YOF</td> <td>0.0000</td> <td></td> </tr> <tr> <td>CF</td> <td>0.0000</td> <td>0.0000</td> </tr> </tbody> </table>			Corg-2004	OOF	YOF	YOF	0.0000		CF	0.0000	0.0000	<table border="1"> <thead> <tr> <th>Corg-2005</th> <th>OOF</th> <th>YOF</th> </tr> </thead> <tbody> <tr> <td>YOF</td> <td>0.0001</td> <td></td> </tr> <tr> <td>CF</td> <td>0.7541</td> <td>0.0005</td> </tr> </tbody> </table>			Corg-2005	OOF	YOF	YOF	0.0001		CF	0.7541	0.0005
Corg-2004	OOF	YOF																					
YOF	0.0000																						
CF	0.0000	0.0000																					
Corg-2005	OOF	YOF																					
YOF	0.0001																						
CF	0.7541	0.0005																					
<table border="1"> <thead> <tr> <th>Corg-04/05</th> <th>OOF</th> <th>YOF</th> </tr> </thead> <tbody> <tr> <td>YOF</td> <td>0.0000</td> <td></td> </tr> <tr> <td>CF</td> <td>0.0094</td> <td>0.0000</td> </tr> </tbody> </table>			Corg-04/05	OOF	YOF	YOF	0.0000		CF	0.0094	0.0000	<table border="1"> <thead> <tr> <th>Corg-rain</th> <th>OOF</th> <th>YOF</th> </tr> </thead> <tbody> <tr> <td>YOF</td> <td>0.0000</td> <td></td> </tr> <tr> <td>CF</td> <td>0.0000</td> <td>0.0000</td> </tr> </tbody> </table>			Corg-rain	OOF	YOF	YOF	0.0000		CF	0.0000	0.0000
Corg-04/05	OOF	YOF																					
YOF	0.0000																						
CF	0.0094	0.0000																					
Corg-rain	OOF	YOF																					
YOF	0.0000																						
CF	0.0000	0.0000																					

Bold numbers indicate significant differences

Rogasik et al. (2004) supported these findings with long-term observations in Germany and showed that the amount of soil organic matter is mainly a function of the used management system. In addition, Capriel (1991), Drinkwater et al. (1995) and Mäder et al. (1993; 2002a, b) found that under organic tillage management the soil carbon content increased more than under conventional management and was more pronounced in the topsoil than in the subsoil (Diez et al., 1991). Amman (1989), Carter and Rennie (1982) and König et al. (1989) found no differences in soil organic carbon between organic and conventional tillage systems in Alberta (USA) and German soils.

According to Campbell et al. (1992) and Dodor and Tabatabai (2005) the organic matter content is a function of the net input of organic residues by rotation practices within cropping systems. The higher organic carbon contents at the organic farming sites compared to the

conventional farming site were expected because the organic farming management is based to increase the soil organic matter content. Edmeades (2003) showed that residues maintain soil organic matter at higher levels than inorganic fertilization does. The accumulation of soil organic carbon at the soil surfaces of the organically managed sites was a result of residues at the soil surface left over from the winter cover crop. This hypothesis was promoted from many other authors (e.g. Alvarez et al., 1995; Armstrong-Brown et al., 1993; Edmeades, 2003; Bandick and Dick, 1999; Dick and Gregorich, 2004; Lal et al., 1994; Petersen et al., 1997; Stolze et al., 2000) who showed that organic and no till management systems, thus the use of organic residues, tend to show higher total soil organic carbon contents than conventionally managed soils.

Contrary to the prospects the YOF site showed higher Corg contents than the OOF site although at the YOF and OOF sites in 2004 and 2005 the same tillage practices were conducted as well as the same summer and winter cover crops were sown. Therefore Reicosky et al. (1995), Schinner and Sonnleitner (1996b) and Skjemstad et al. (1998) discussed that factors such as topography, clay content, mineralogy, pH-value, redox potential and soil structure could influence soil organic matter levels. The hypothesis for the higher Corg content at the YOF site is that more residues were left at the YOF soil surface than at the OOF soil surface although the same cultivation practices were accomplished. The higher Corg content is maybe not coupled with higher clay and humus complexes and therefore the enzyme activities of acid-phosphatase and β -glucosidase were at the YOF site not higher than at the OOF site. If this hypothesis is true, the time of conversion from conventional to organic farming have therefore a great influence of clay humus complex formation which are important for the enzyme activities. Another hypothesis for this pattern is that the quality of organic matter is at the OOF site higher than at the YOF site. Acosta-Martinez et al. (2003b) showed in sandy Texas soils that the enzyme activities of phosphatases and glucosidases reflected the differences in soil organic matter quality and quantity developed under alternative systems and conventional tillage practices and suggested that not only the quantity of soil organic matter, but also the chemical nature of organic matter has an impact on soil microbial activities and processes. Doran et al. (1998) stated in earlier findings that soil management practices can influence soil biological activities through their effects on the quantity, structure, and distribution of soil organic matter. In addition Ekenler and Tabatabai (2002) found in Iowa soils that enzyme activity values could be used as indexes of organic C quality.

The regression analysis between organic carbon content and enzyme activities of acid-phosphatase and β -glucosidase showed in general positive and significant correlations at the OOF, YOF and CF sites with an exception of β -glucosidase at the YOF site (Table 20). Due to the weak dynamic changes of Corg in the laboratory rainfall experiment the correlation analysis between the Corg content and the enzyme activities was not valid.

Table 20 Correlation coefficients (R)^a between acid-phosphatase as well as β -glucosidase and the organic carbon (Corg) content in the field experiment 2004, 2005 as well as for 2004/2005

site	year	enzyme	Corg		
			2004	2005	2004/2005
OOF	2004	Pho	0.634***	0.390**	0.445**
	2005				
	2004/2005				
YOF	2004		0.586***	0.311*	0.378*
	2005				
	2004/2005				
CF	2004		0.425**	0.594***	0.656***
	2005				
	2004/2005				
OOF	2004	Glu	0.770***	0.614***	0.600***
	2005				
	2004/2005				
YOF	2004		0.464**	0.127 ^{n.s.}	0.225 ^{n.s.}
	2005				
	2004/2005				
CF	2004		0.490**	0.727***	0.696***
	2005				
	2004/2005				

^a Level of significance: * P < 0.05, ** P < 0.01, *** P < 0.001, n.s. not significant

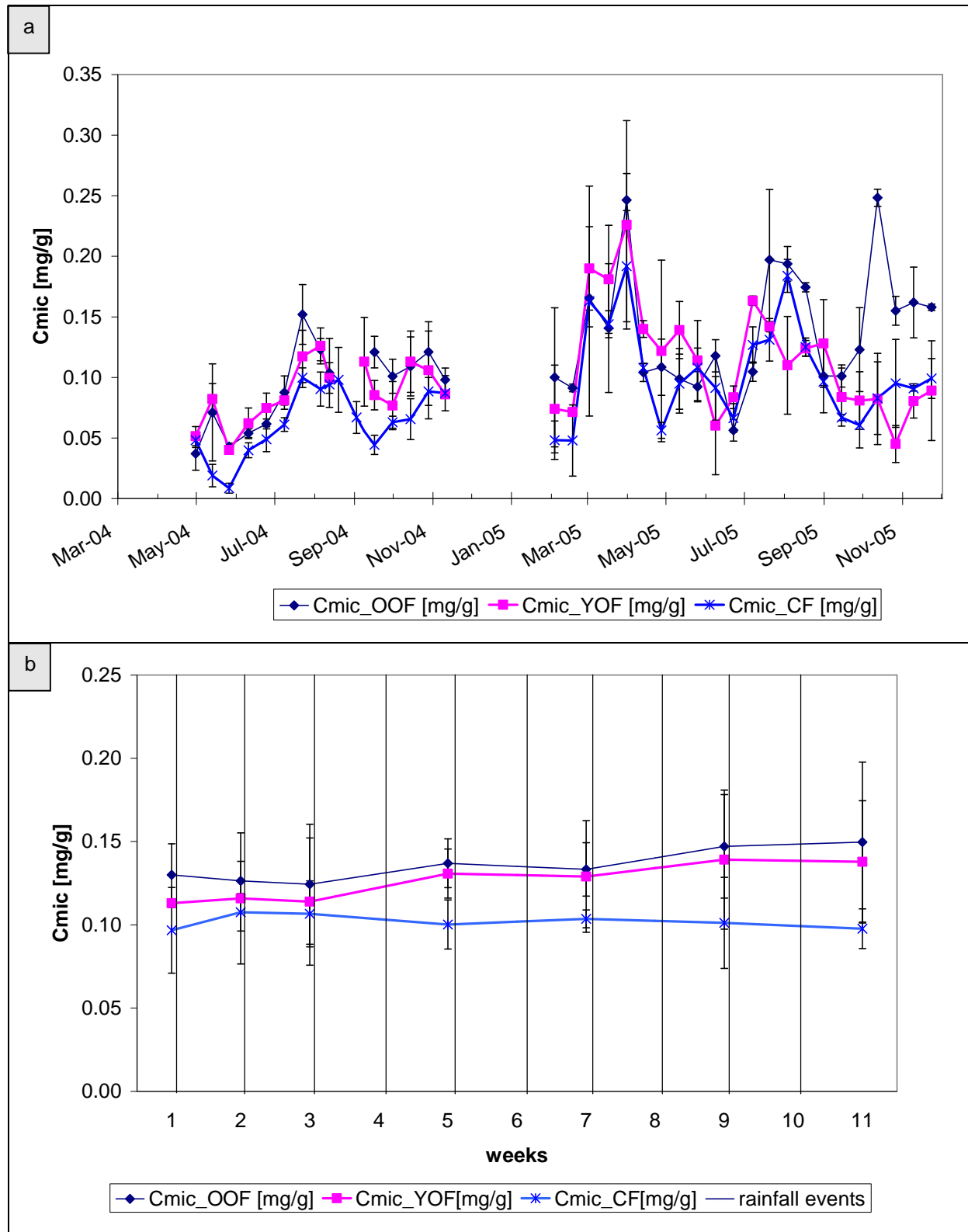
Significant correlation coefficients between Corg and enzyme activities were also found from other researchers. For example Acosta-Martinez et al. (2004) found for β -glucosidase in fine sandy Texas soils correlation coefficients of R=0.64*** as well as Dodor and Tabatabai (2005) detected in the upper 15 cm of Iowa soils correlation coefficients of R=0.33*. For acid-phosphatase Graham and Haynes (2005) found in South African soils significant correlations coefficients of R=0.91*** as well as Acosta-Martinez et al. (2004) found in fine sandy Texas soils correlation coefficients of R=0.48**. However Green et al. (2006) found in Brazilian Cerrado soils no significant correlation to the β -glucosidase with correlation coefficients of e.g. R=0.30^{n.s.}. Furthermore Deng and Tabatabai (1997) and Dick (1984) observed that the activity of a range of soil enzymes was significantly correlated with soil organic C in soils under different tillage management.

The positive and significant correlations at the organic and conventional management systems were not surprising because the β -glucosidase is involved in the soil carbon cycle and the hydrolysis products of these enzymes are believed to be important energy sources for the growth of soil microorganisms (Deng and Tabatabai, 1996a). Martens et al. (1992) reported that β -glucosidase activity was significantly increased by the addition of plant material due to the addition of enzymes present in plant residues. Furthermore Beck and Beck (2000), Deng and Tabatabai (1996a, b; 1997), Ekenler and Tabatabai (2002), Klose and Tabatabai (2000), Lal (1990) and Schinner and Sonnleitner (1996a) assumed that increased enzyme activity is a result of residues at the soil surface. In addition legumes in crop rotations increased the organic C and thereby the soil microbial biomass and enzyme activities (Bolton et al., 1985; Kennedy, 1999).

5.1.4 Microbial carbon

Soil microbial biomass is the living component of soil organic matter and involved in the decomposition of organic materials and cycling of nutrients in soils (Bergstrom et al., 1998; Dick, 1992; Dodor and Tabatabai, 2003; Jenkinson and Ladd, 1981; Klose and Tabatabai, 1999). The microbial carbon content is according to Jenkinson and Ladd (1981) and Moore et al. (2000) 1.0 % to 3.0 % of Corg content and according to Omay et al., (1997) between 0.3 % up to 7 % of Corg. The microbial biomass is a very labile pool and can therefore be used as an early indicator of changes in soil management systems compared to total organic C (e.g. Bergstrom et al., 1998; Brookes, 1995; Carter, 1986; Dodor and Tabatabai, 2003; Gregorich et al., 1997; Haynes and Beare, 1996; Klose and Tabatabai, 1999; Lal, 1997; Powlson et al., 1987; Sparling, 1997; Trasar-Cepeda et al., 1998). The soil microbial biomass is responsible for several transformations, decomposition processes and cycles of nutrients in soils (Bailey et al., 2002; Tessier et al., 1998) and has become an instrument for determining the total microbial biomass since it was first reported of Jenkinson and Powlson (1976). According to Bailey et al. (2002) and Vance et al. (1987) the used chloroform fumigation-extraction method is a quick, simple, robust and stable procedure to extract the released C, and is less restricted by soil conditions than other methods (Beck et al., 1997; Inubushi et al., 1991; Ross, 1989; Sparling et al., 1990).

In Fig. 80 the microbial carbon content at the YOF, OOF and CF sites at the field experiment in 2004 and 2005 as well as at the laboratory rainfall experiment is shown.



Error bars indicate the standard deviation between 3 replications

Fig. 80 Microbial carbon (Cmic) content at the OOF, YOF and CF sites in the field (a) and laboratory rainfall experiment (b)

To analyze the dynamic changes of microbial carbon in the upper 3 cm of the soil surface the Box-Whisker-Plot analysis was carried out to show the mean as well as the standard deviation in the field and rainfall experiment (Fig. 81). A possible explanation for the dynamic

changes could be that the different root characteristics and functions (Chan and Heenan, 1999; Schinner and Sonnleitner, 1996a) as well as microclimate and soil structure (Moore et al., 2000) influence the microbial carbon content. Chang and Juma (1996) and Kaiser et al. (1995) reported temporal fluctuations of C_{mic} as a result of variations in soil moisture content, soil temperature, stage of plant growth, and available substrate. Green et al. (2006) stated that the soil biological system is in constant flux due to environmental changes. Thereby changes in soil physical or chemical properties often affect soil biological activity.

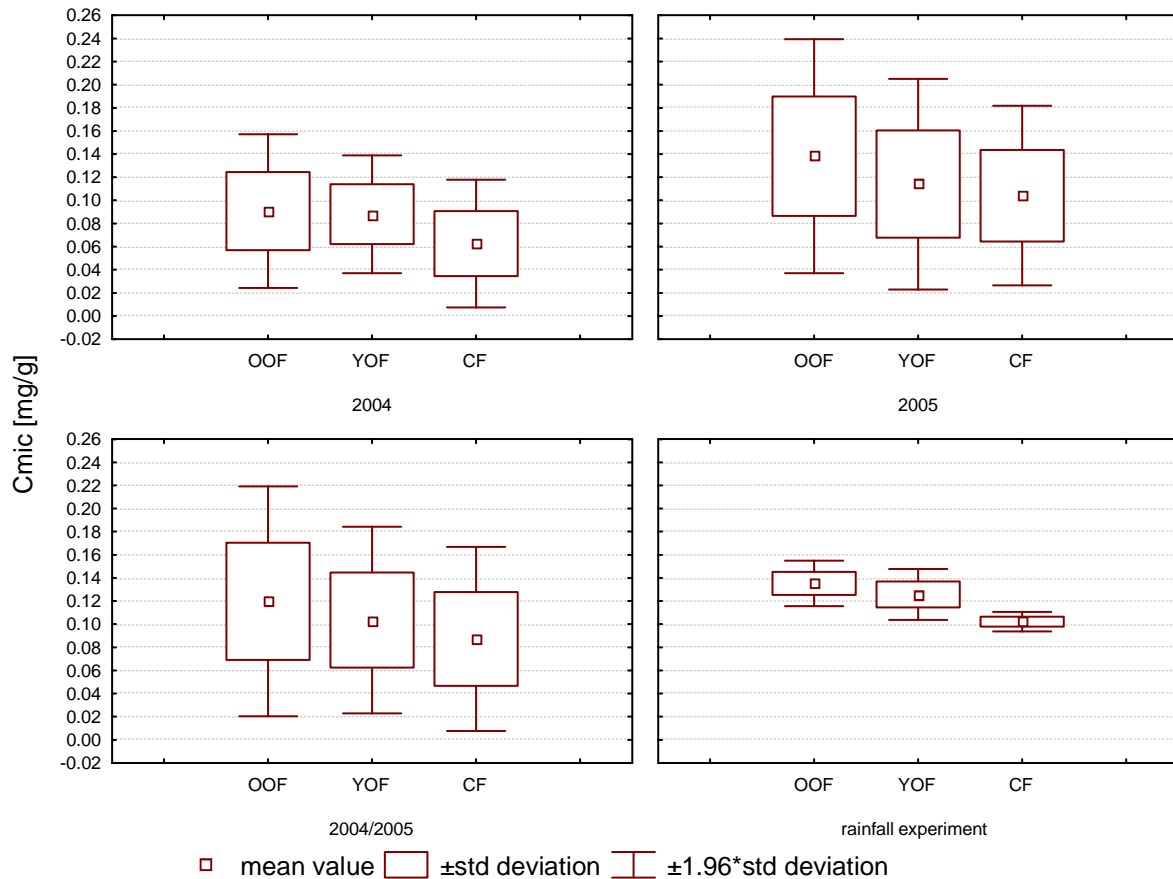


Fig. 81 Box-Whisker-Plot design for microbial carbon content at the OOF, YOF and CF site in the field (2004, 2005 as well as considered together 2004/2005) and rainfall experiment

The Box-Whisker-Plot analysis showed for 2004/2005 that the C_{mic} content (as mean value) at the OOF (0.120 mg/g) site was higher than at the YOF (0.104 mg/g) site. Both organic managed sites showed higher C_{mic} contents than the CF site (0.086 mg/g). The recently established organic farming site (YOF) could be understood as an interstage between the conventionally farming system (CF) and the well established organic farming system (OOF). Kahle et al. (2004) and Mäder (2002a, b) also found higher C_{mic} contents in organically management systems than in conventional farming systems. However Hoffmann et al. (2006) found higher C_{mic} contents (0.3 mg/g to 0.4 mg/g) in fertilized than in unfertilized soils.

The results of Corg showed that the YOF site had the highest content, the OOF medium content and the CF site the lowest content. The results for Cmic showed however that at the OOF site the Cmic content is higher than at the YOF and CF site. This finding indicates that not only the total Corg content is responsible for the Cmic content rather the easily available soil organic matter compounds (which are the preferred energy sources for microorganisms) caused in higher microbial biomass contents and activities (Ekenler and Tabatabai, 2003a). The results of the regression analysis showed furthermore that the Corg content was at the OOF site higher correlated to the Cmic content ($R=0.448^{**}$) than at the YOF site ($R=0.247^*$). The CF site showed a significant correlation between both parameters ($R=0.523^{**}$). This indicates that not only the quantity of soil organic matter, but also the chemical nature of organic matter influence soil microbial activities and processes (Acosta-Martinez et al., 2003b).

The one way ANOVA (Table 21) showed in 2004 that the microbial carbon content at all three sites were not significantly different; in 2005 the OOF site was significantly different to the CF site. In the rainfall experiment the microbial carbon content at both organic farming soils was significantly higher than the conventional soils.

Table 21 One factor analysis of variance (ANOVA) for microbial carbon content in 2004, 2005, 2004/2005 in the field and rainfall experiment

Cmic-2004			Cmic-2005		
YOF	OOF	YOF	YOF	OOF	YOF
	0.8568			0.0505	
CF	0.0644	0.0887	CF	0.0060	0.4133
Cmic-04/05			Cmic-rain		
YOF	OOF	YOF	YOF	OOF	YOF
	0.1212			0.0633	
CF	0.0022	0.1185	CF	0.0000	0.0001

Bold numbers indicate significant differences

Balota et al. (2003) and Melero et al. (2006) as well found a significant increase of soil microbial carbon under no till and organic tillage management compared to conventional tillage. According to Campbell et al. (1992) and Omay et al. (1997), increased Cmic values are normally found in high residue producing rotations and under reduced or no till systems. Furthermore Scow et al. (1994) and Drinkwater et al. (1995) showed that organic farming plots had higher microbial biomass levels than plots receiving commercial fertilizers. The positive effect on microbial biomass at the organically farmed sites may be due to the greater amounts and diversity of residues (Arshad et al., 1990), favorable crop residue management of the organic management system (Graham and Haynes, 2005) and higher root density under varied crop rotations (Moore et al., 2000). Furthermore the higher Cmic content at the organically managed sites could indicate that the light organic matter fraction decomposed

more completely in organic systems than in conventional systems (Fließbach and Mäder, 2000). Hence, the increased microbial activity in organic managed soils transform carbon from organic debris into biomass at lower energy costs, building up a higher microbial biomass content (Mäder et al., 2002a, b). For example, Lynch and Panting (1980) showed strong increases in Cmic as response to decomposing incorporated crop residues and roots providing substantial energy for the microbial biomass (Perrott et al., 1990) which stimulates the soil microbial biomass growth (Buchanan and King, 1992).

In general it could be concluded that the microbial carbon content was positive and significantly correlated with the enzyme activities of acid-phosphatase and β -glucosidase at the field experiments (Table 22). The correlation coefficients at the rainfall experiment were not valid due to weak dynamic changes of Cmic and acid-phosphatase and β -glucosidase.

Table 22 Correlation coefficients (R)^a between acid-phosphatase as well as β -glucosidase and the microbial carbon (Corg) content in the field experiment in 2004, 2005 as well as for 2004/2005

site	year	enzyme	Cmic		
			2004	2005	2004/2005
OOF	2004	Pho	0.892***	0.645***	0.720***
	2005				
	2004/2005				
YOF	2004		0.890***	0.605***	0.529***
	2005				
	2004/2005				
CF	2004		0.721***	0.562***	0.682***
	2005				
	2004/2005				
OOF	2004	Glu	0.901***	0.717***	0.718***
	2005				
	2004/2005				
YOF	2004		0.866***	0.680***	0.653***
	2005				
	2004/2005				
CF	2004		0.658***	0.533***	0.626***
	2005				
	2004/2005				

^aLevel of significance: * P < 0.05, ** P < 0.01, *** P < 0.001, n.s. not significant

The high and significant correlations between the Cmic content and the enzyme activities in the field experiment were supported by a large number of researchers (e.g. Curci et al., 1997; Deng et al., 2000; Dodor and Tabatabai, 2002; 2003; 2005; Graham and Haynes, 2005; Klose and Tabatabai, 1999; Knight and Dick, 2004; Moore et al., 2000). They also found positive and significant correlations between Cmic and acid-phosphatase (e.g. R=0.83***, R=0.97***) and β -glucosidase (e.g. R=0.33*, R=0.50**, R=0.82***). In addition Ekenler and Tabatabai (2003) found in Iowa soils positive correlations between acid-phosphatase and Cmic as well but also sometimes negative significant correlations at

different sampling times. Furthermore Acosta-Martinez (2004) found in a sandy Texas soil positive (e.g. $R=0.35^*$, $R=0.48^{**}$) as well no significant correlations between the microbial carbon content and the activity of β -glucosidase at different sampling times and no significant correlations to the acid-phosphatase activity during the experimental period (four sampling times in one year).

The high and significant correlation coefficients were not surprising, because β -glucosidase and acid-phosphatase were among other things produced from soil microbes to convert complex organic compounds into smaller products (Beck and Beck, 2000; Nannipieri et al., 2002; Tabatabai, 1994). These enzymes are cellulose degrading enzymes such as β -glucosidase which is a key enzyme in the carbon cycle (e.g. Klose et al., 2003). The carbon degrading microbes must also produce phosphatases to obtain nutrients and enzyme synthesis (Sinsabaugh et al., 1992a, b). Mäder et al. (2002a, b) supported this finding and mentioned that higher microbial activity is indicating higher enzyme activity. Dilly and Nannipieri (2001) showed for arable and forest soils that negative or no correlations between the microbial biomass and the enzyme activity could be possible due to the reason that enzyme activities are constitutive or inducible and their synthesis can be induced by specific compounds.

5.1.5 Cmic/Corg ratio

The Cmic/Corg ratio is generally used in the literature as an indicator for changes in soil microbial activity (Dick, 1992; Pankhurst et al., 1995; Powlson, 1994) and for metabolic activity which might be affected by changing management conditions and climate (Anderson and Domsch, 1989, Sparling, 1992; Weigand et al., 1995). The Cmic content represents the active part of soil organic carbon. The rate of easily decomposable organic C compared to stable humus compounds is depending on the Cmic/Corg ratio, because this ratio is an indicator of the availability of soil organic matter to microorganisms (Anderson and Domsch, 1989).

The Cmic/Corg ratio in the field experiment ranged between 0.39 % and 2.25 % at the OOF site, 0.45 % and 1.82 % at the YOF site and 0.11 % and 2.01 % at the CF site. In the rainfall experiment the dynamic Cmic/Corg ratio changes were weaker than during the field experiment (Fig. 82).

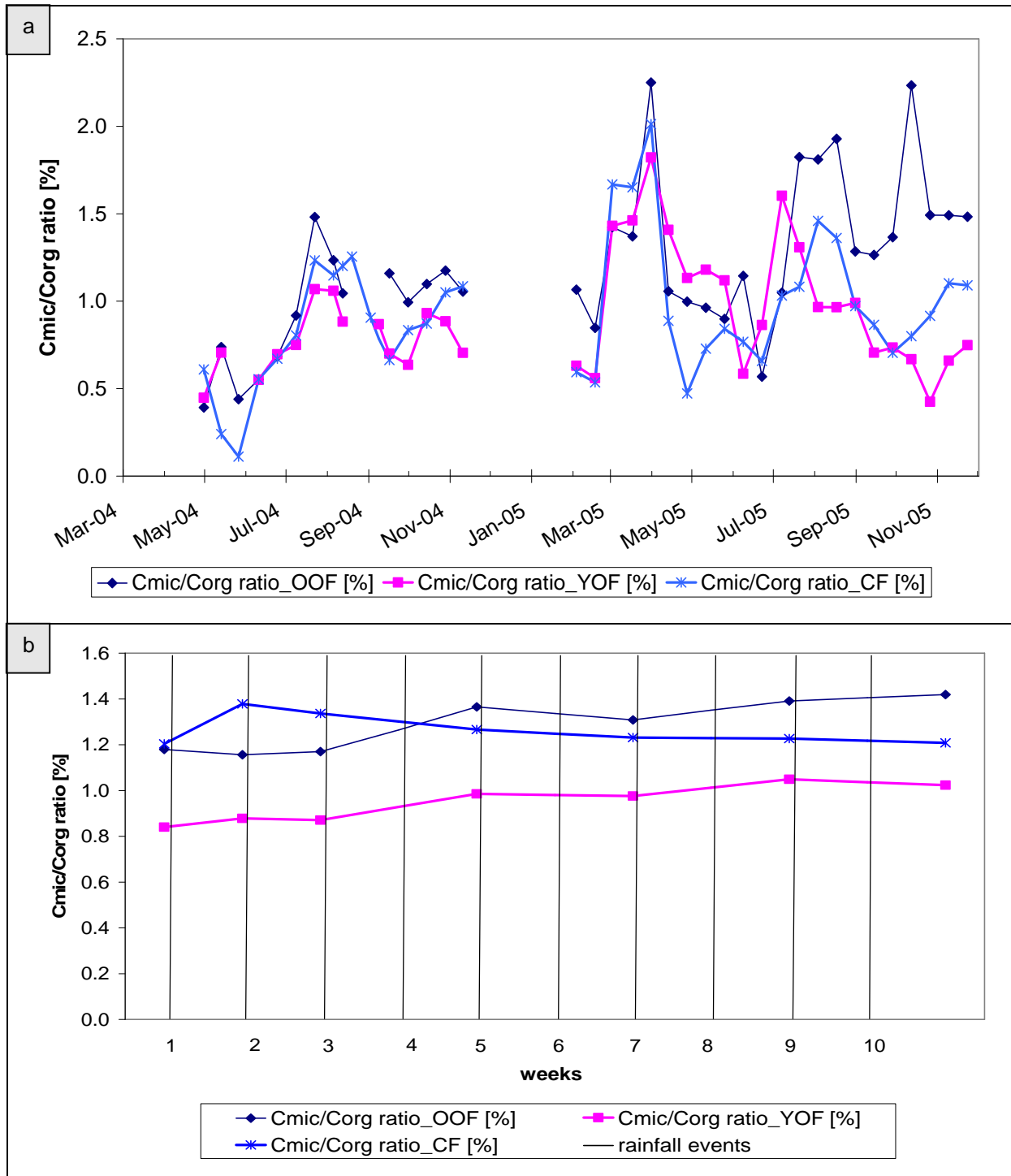


Fig. 82 Cmic/Corg ratio at the OOF, YOF and CF sites in the field (a) and laboratory rainfall experiment (b)

The dynamic changes of the Cmic/Corg showed high correlation between the OOF, YOF and CF site in 2004 as well as in early 2005. Insam et al. (1991) explained in long-term experimental sites in Alabama (USA) 78 % of the Cmic/Corg ratio variability by climatic conditions (precipitation/evaporation quotient). Long-term experiments of different climatic region showed that the Cmic/Corg ratio was lower under balanced precipitation and evaporation conditions and higher in dry or more humid conditions (Insam et al., 1989).

Sparling (1992) found in New Zealand soils that cropping and vegetation management affected the Cmic/Corg ratio more than climate conditions. Wick (1997) stated that a deficit of this indicator is that the components Cmic and Corg were not independent of each other.

However the Box-Whisker-Plots for the Cmic/Corg ratio indicated only small variations of the mean deviation between the three sites in the field experiment. However the Cmic/Corg ratio was in general higher at the OOF site than at the YOF and CF sites (Fig. 83).

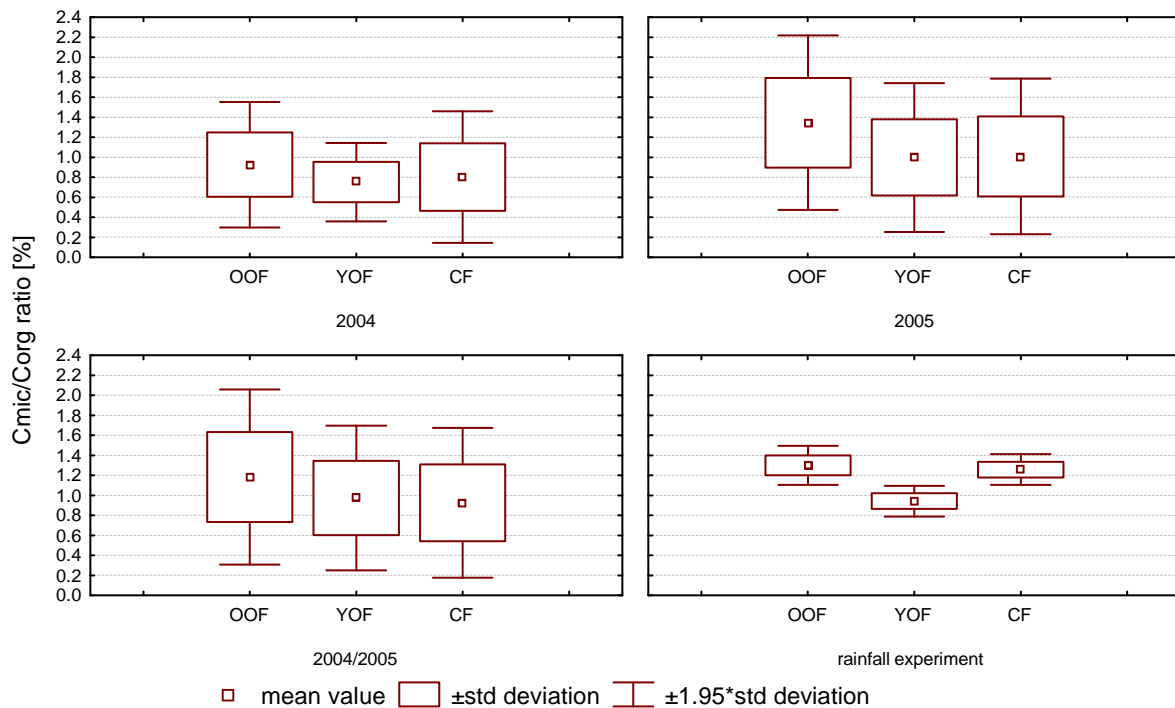


Fig. 83 Box-Whisker-Plot design for the Cmic/Corg ratio at the OOF, YOF and CF site in the field (2004, 2005 as well as considered together 2004/2005) and rainfall experiment

The YOF site is therefore an interstage between the OOF site and the CF site. The results obtained from the Box-Whisker-Plots were supported from the analysis of variance (Table 23).

Table 23 One factor analysis of variance (ANOVA) for Cmic/Corg ratio in 2004, 2005, 2004/2005 in the field and rainfall experiment

Cmic/Corg ratio-2004	OOF	YOF	Cmic/Corg ratio-2005	OOF	YOF
YOF	0.6755		YOF	0.0105	
CF	0.3866	0.6481	CF	0.0043	0.7553
Cmic/Corg ratio-04/05	OOF	YOF	Cmic/Corg ratio-rain	OOF	YOF
YOF	0.0283		YOF	0.0000	
CF	0.0075	0.6145	CF	0.3655	0.0000

Bold numbers indicate significant differences

In 2004 the Cmic/Corg ratio was not influenced by the management system but in 2005 and for the total period 2004/2005 the OOF site was significantly different to the YOF and CF site. This result was supported by earlier findings from Hart et al. (1989) who showed that different Cmic/Corg ratios are depending on changes in soil organic matter resulting from different land management. The Cmic/Corg ratio at the YOF site was not significantly different to the Cmic/Corg ratio at the CF site. This may indicate that the date of conversion from conventional to organic farming is significant for the Cmic/Corg ratio.

The SAS linear regression model showed high positive and significant correlations between the Cmic/Corg ratio and the enzyme activities of acid-phosphatase and β -glucosidase at all three sites at the field experiment with only one exception at the CF site in 2005 where no correlation could be found (Table 24). For the rainfall experiment no correlations were calculated, because the enzyme activities as well as the Cmic/Corg ratio showed only little variations.

Table 24 Correlation coefficients (R)^a between acid-phosphatase as well as β -glucosidase and the Cmic/Corg ratio in the field experiment in 2004, 2005 as well as for 2004/2005

site	year	enzyme	Cmic/Corg ratio		
			2004	2005	2004/2005
OOF	2004	Pho	0.876***	0.575***	0.677***
	2005				
	2004/2005				
YOF	2004		0.846***	0.568***	0.481**
	2005				
	2004/2005				
CF	2004		0.708***	0.304 ^{n.s.}	0.470**
	2005				
	2004/2005				
OOF	2004	Glu	0.869***	0.563***	0.622***
	2005				
	2004/2005				
YOF	2004		0.834***	0.704***	0.650***
	2005				
	2004/2005				
CF	2004		0.632***	0.207 ^{n.s.}	0.327*
	2005				
	2004/2005				

^a Level of significance: * P <0.05, ** P <0.01, *** P <0.001, n.s. not significant

5.1.6 Nitrogen

Nitrogen is a key plant nutrient necessary for high yields of most agricultural crops. Nitrogen in the NO_3 form is also mobile and susceptible to leaching into the groundwater, causing degradation of water quality (Pang and Letey, 2000). Conversion from mineral fertilizer to organic forms such as liquid manure or plant residues changes the soil structure. The added residues increase soil organic matter and nitrogen content thus increasing soil fertility (Ashraf et al., 2004).

The Box-Whisker-Plot analysis (Fig. 84) as well as the analysis of variance (Table 25) showed that the nitrogen content was in general significantly influenced by the used management system (with an exception in 2005 where the OOF site was not significantly different to the CF site).

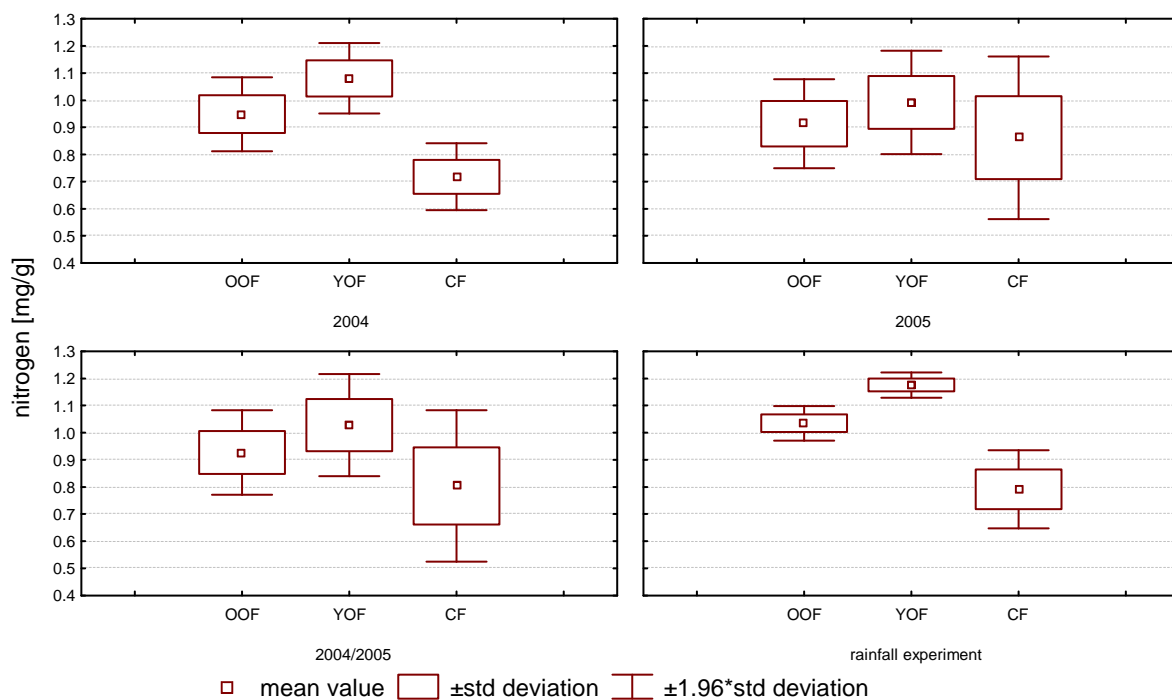


Fig. 84 Box-Whisker-Plot design for the nitrogen content at the OOF, YOF and CF site in the field (2004, 2005 as well as considered together 2004/2005) and rainfall experiment

Table 25 One factor analysis of variance (ANOVA) for nitrogen content in 2004, 2005, 2004/2005 in the field and rainfall experiment

<u>nitrogen-2004</u>	<u>OOF</u>	<u>YOF</u>	<u>nitrogen-2005</u>	<u>OOF</u>	<u>YOF</u>
YOF	0.0004		YOF	0.0095	
CF	0.0000	0.0000	CF	0.0877	0.0000
<u>nitrogen-04/05</u>	<u>OOF</u>	<u>YOF</u>	<u>nitrogen-rain</u>	<u>OOF</u>	<u>YOF</u>
YOF	0.0001		YOF	0.0000	
CF	0.0000	0.0000	CF	0.0000	0.0000

Bold numbers indicate significant differences

This finding was supported by results of Green et al. (2006) who found that the nitrogen content was influenced by the soil management system and was sensitive to changes in tillage management of a Brazilian Oxisol.

In addition the Box-Whisker-Plots showed that the nitrogen content at the recently established organic farming site (YOF) was significantly higher than at the well established organic farming site (YOF). Both organic farming sites showed as well higher nitrogen contents (mean value) than the conventional farming site. A related pattern was also found for the organic carbon content. The higher nitrogen content at the organic farming site was expected, because organic carbon and nitrogen were among other things (e.g. crop rotation, soil, plowing depth and atmosphere emission influenced soil C and N) influenced from residues and fertilization (Schmidt and Merbach, 2004).

The correlation coefficients to the enzyme activity of acid-phosphatase and β -glucosidase at the field experiment were mostly high and significant, even though in some exceptions no significant correlation coefficients could be found (Table 26).

Table 26 Correlation factors (R)^a between acid-phosphatase as well as β -glucosidase and the nitrogen content in the field experiment in 2004, 2005 as well as for 2004/2005

site	year	enzyme	nitrogen		
			2004	2005	2004/2005
OOF	2004	Pho	0.577***	0.567***	0.488**
	2005				
	2004/2005				
YOF	2004		0.329*	0.283 ^{n.s.}	0.322*
	2005				
	2004/2005				
CF	2004		0.023 ^{n.s.}	0.501**	0.545***
	2005				
	2004/2005				
OOF	2004	Glu	0.628***	0.524**	0.512**
	2005				
	2004/2005				
YOF	2004		0.529**	0.161 ^{n.s.}	0.063 ^{n.s.}
	2005				
	2004/2005				
CF	2004		0.224 ^{n.s.}	0.435**	0.448**
	2005				
	2004/2005				

^a Level of significance: * P < 0.05, ** P < 0.01, *** P < 0.001, n.s. not significant

Green et al. (2006) showed that enzyme activities of acid-phosphatase ($R=0.70^{**}$) and β -glucosidase ($R=0.46^*$) were significantly correlated with total N and Acosta-Martinez et al. (2004) showed also positive significant correlations but sometimes no significant correlations to the acid-phosphatase and β -glucosidase activity. In addition Klose and Tabatabai (2002b) found only weak correlations between acid-phosphatase and nitrogen. These findings were in accordance to my experiences

5.1.7 C/N ratio

The type of crop residues plays an essential role in carbon sequestration and soil aggregation because the degradation rate of crop residues is frequently dominated by the C/N ratio (Franzluebbers et al., 1995a; Oades, 1988; Potter et al., 1998). The C/N ratio according to Bird et al. (2002) is a good value to predict aggregate stability, because soil aggregation as well aggregate stability were affected by the C/N ratio and the quality of crop residues (Lynch and Bragg, 1985). In the field experiment the C/N ratio oscillated at the organically and conventionally managed farming around 10 which indicated good conditions for microbial conversion (Kahle et al., 2004). In general at the conventional farming site the C/N ratio in the field experiment was higher than at the organic farming sites (Fig. 85).

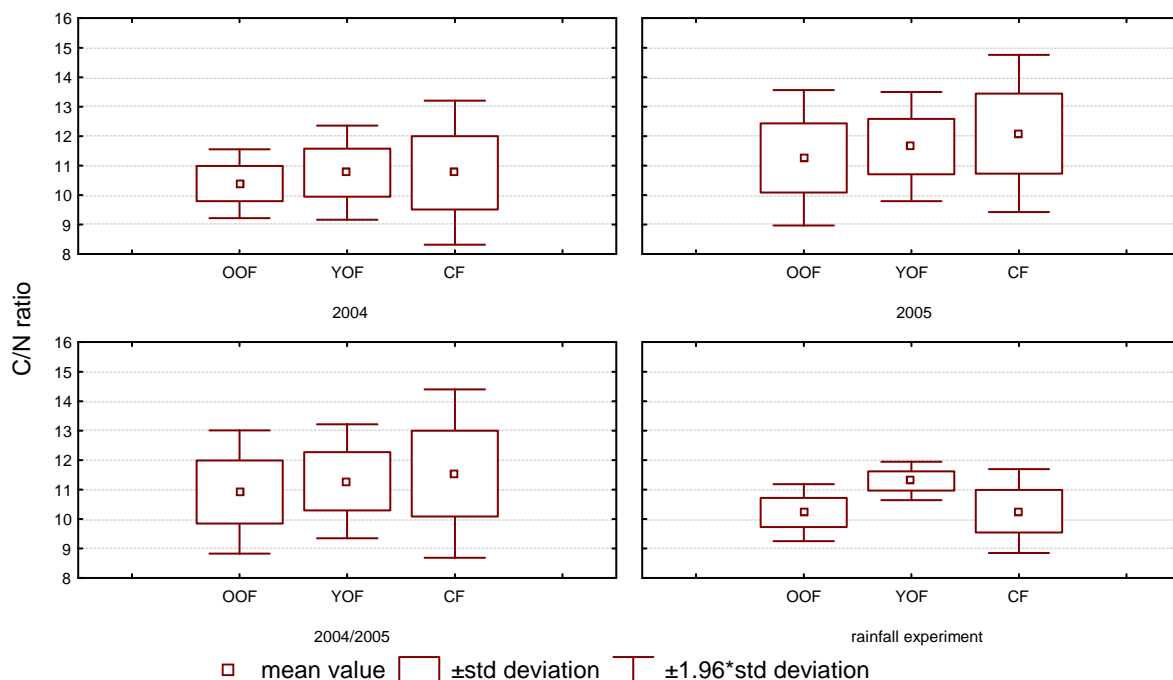


Fig. 85 Box-Whisker-Plot design for the C/N ratio at the OOF, YOF and CF site in the field (2004, 2005 as well as considered together 2004/2005) and rainfall experiment

However Beck and Beck (2000) mentioned that composted organic fertilizers with low C/N ratio support the enzyme activity of β -glucosidase. Furthermore the ANOVA (Table 27) showed that in general the well established organic farming site (OOF) was different to the conventional farming site (CF).

Table 27 One factor analysis of variance (ANOVA) for C/N ratio in 2004, 2005, 2004/2005 in the field and rainfall experiment

C/N-2004	OOF	YOF	C/N-2005	OOF	YOF
YOF	0.3614		YOF	0.2429	
CF	0.3675	0.9906	CF	0.0131	0.1799
C/N-04/05	OOF	YOF	C/N-rain	OOF	YOF
YOF	0.1948		YOF	0.0016	
CF	0.0272	0.3487	CF	0.8724	0.0023

Bold numbers indicate significant differences

However the aggregation ratio as well as the enzyme activities of acid-phosphatase and β -glucosidase showed no significant correlations to the C/N ratio at the conventional and organic managed soils (Table 28, Table 29).

Table 28 Correlation coefficients (R)^a between acid-phosphatase as well as β -glucosidase and the C/N ratio in the field experiment in 2004, 2005 as well as for 2004/2005

site	year	enzyme	C/N ratio		
			2004	2005	2004/2005
OOF	2004	Pho	0.314 ^{n.s.}		
	2005			0.106 ^{n.s.}	
	2004/2005				0.030 ^{n.s.}
YOF	2004		0.211 ^{n.s.}		
	2005			0.005 ^{n.s.}	
	2004/2005				0.011 ^{n.s.}
CF	2004		0.155 ^{n.s.}		
	2005			0.002 ^{n.s.}	
	2004/2005				0.230 ^{n.s.}
OOF	2004	Glu	0.266 ^{n.s.}		
	2005			0.176 ^{n.s.}	
	2004/2005				0.102 ^{n.s.}
YOF	2004		0.065 ^{n.s.}		
	2005			0.320 ^{n.s.}	
	2004/2005				0.145 ^{n.s.}
CF	2004		0.439 ^{**}		
	2005			0.363 [*]	
	2004/2005				0.471 ^{**}

^aLevel of significance: * P < 0.05, ** P < 0.01, *** P < 0.001, n.s. not significant

Table 29 Correlation coefficients (R)^a between aggregation ratio and the C/N ratio in the field experiment in 2004, 2005 as well as for 2004/2005

site	year	variable	aggregation ratio		
			2004	2005	2004/2005
OOF	2004	C/N ratio	0.337*	0.397*	0.134 ^{n.s.}
	2005				
	2004/2005				
YOF	2004		0.190 ^{n.s.}	0.360*	-0.128 ^{n.s.}
	2005				
	2004/2005				
CF	2004		0.052 ^{n.s.}	0.061 ^{n.s.}	-0.203 ^{n.s.}
	2005				
	2004/2005				

^aLevel of significance: * P <0.05, ** P <0.01, *** P <0.001, n.s. not significant

Zotarelli et al. (2005) showed that the C/N ratio of aggregates (same size class and same depth) were not significantly different between tillage treatments (no tillage – conventional tillage) of Brazilian Oxisols. In addition Ding et al. (2006) showed that the C/N ratios of a Massachusetts (USA) fine sandy loam were not significantly affected by cover crop and fertilizer treatments. Bird et al. (2002) showed correlation coefficients of R=0.81** and R=0.74** between the aggregate stability at the 250 µm scale and C/N ratio in semiarid rangelands soils. But however Tisdall (1996) and Lal et al. (1998) showed that aggregates smaller than 250 µm are more stable than larger aggregates and that the organic carbon inside the small aggregates is protected against breakdown.

5.1.8 pH-value

Carbonates influence soil chemical properties, e.g., pH-value (Moreno et al., 2006). The decrease of pH-values in N-fertilized soils may be due to the nitrification of NH₄ and subsequent production of H⁺ ions, as well as loss of exchangeable Ca and Mg from the topsoil, thus increasing the soil acidity (Graham and Haynes, 2005; McAndrew and Malhi, 1992). Ekenler and Tabatabai (2003b) demonstrated on agricultural used Iowa soils that acid-phosphatase was mostly predominant and decreased with increasing pH by liming. They mentioned that acid-phosphatase was the most sensitive enzyme to changes in soil pH. As reported by Eivazi and Tabatabai (1977); Juma and Tabatabai (1978); Tabatabai (1994) the rate of synthesis, release, and stability of acid-phosphatase by soil microorganisms are dependent on soil pH. In general each enzyme has a pH-value, at which the activity rate is optimal. At each side of this optimum the activity rate is lower. Enzymes are usually most stable near there optimum pH, and they could be irreversibly denatured with extreme pH-values. Furthermore the soil pH-value can greatly influence the rate of enzyme-catalyzed reactions since a change in H⁺ ion concentration influences enzymes, substrates and co-factors by altering their ionization and solubility (Tabatabai 1994). The optimal pH-

value for acid-phosphatase is at pH 5.5 (Ladd and Butler, 1972; Tabatabai, 1994) and for β -glucosidase at pH 6.0 (Eivazi and Tabatabai, 1990). Under acid soil conditions (i.e. < pH 5.5), there are large increases in concentrations of Al^{3+} and Mn^{2+} in soil solution (Rowell, 1988) and high concentrations of these ions could influence enzyme function (Dick, 1997).

The Box-Whisker-Plot analysis (Fig. 86) showed mean pH-values for 2004/2005 of pH=6.14 at the OOF site, pH=6.36 at the YOF site and pH=6.23 at the CF site.

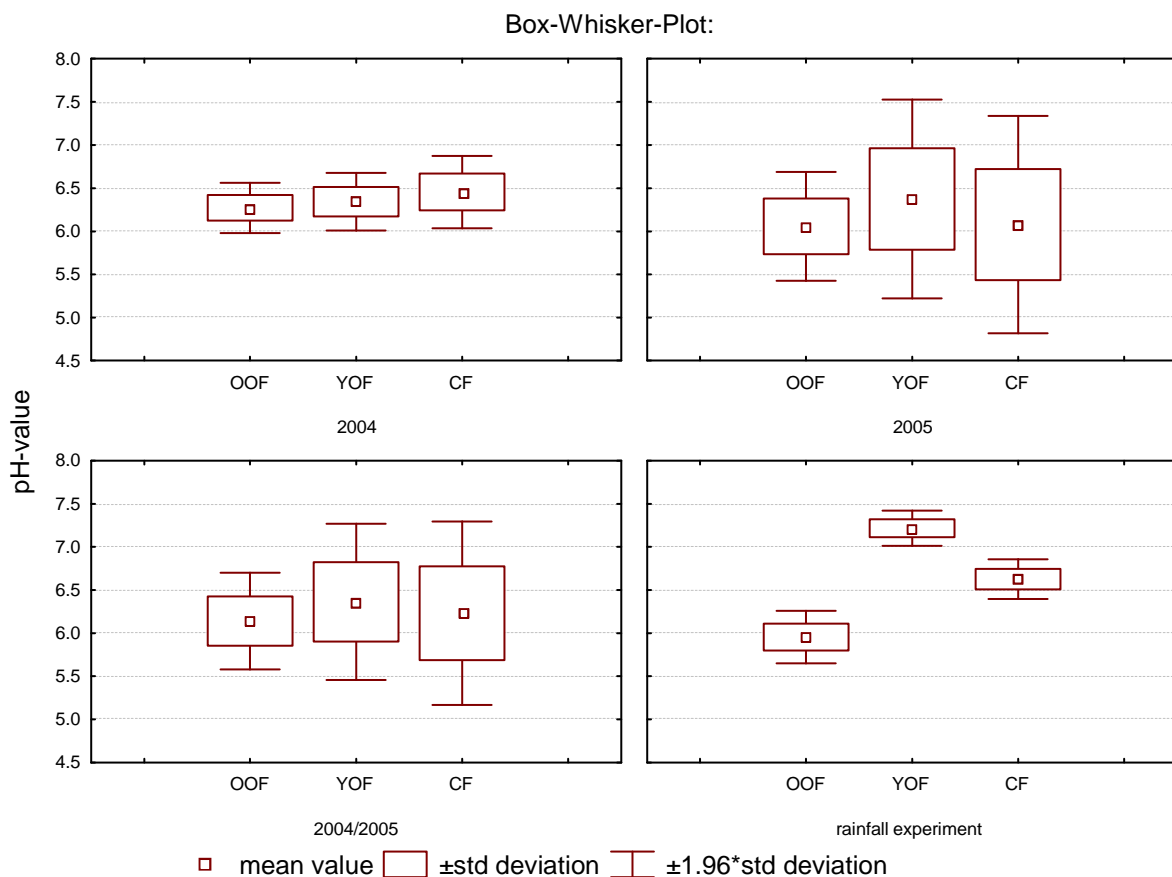


Fig. 86 Box-Whisker-Plot design for the pH-value at the OOF, YOF and CF site in the field (2004, 2005 as well as considered together 2004/2005) and rainfall experiment

In addition to the Box-Whisker-Plots the ANOVA (Table 30) showed for 2004, 2005 and for 2004/2005 no valid results that the pH-value was influenced from the management system. However the ANOVA showed for the rainfall experiment that the pH value at the OOF, YOF and CF soil was significantly influenced from the farming system.

Table 30 One factor analysis of variance (ANOVA) for pH-value in 2004, 2005, 2004/2005 in the field and rainfall experiment

pH-2004	OOF	YOF	pH-2005	OOF	YOF
YOF	0.6525		YOF	0.0169	
CF	0.2551	0.4824	CF	0.8756	0.0253
pH-04/05	OOF	YOF	pH-rain	OOF	YOF
YOF	0.0358		YOF	0.0000	
CF	0.3875	0.2081	CF	0.0000	0.0000

Bold numbers indicate significant differences

The correlation analysis showed in general no significant correlations between the pH-value and the enzyme activities of acid-phosphatase and β -glucosidase. Even though, positive as well as negative significant correlations were found (Table 31).

Table 31 Correlation coefficients (R)^a between acid-phosphatase as well as β -glucosidase and pH-value in the field experiment in 2004, 2005 as well as for 2004/2005

site	year	enzyme	pH-value		
			2004	2005	2004/2005
OOF	2004	Pho	0.328 ^{n.s.}	0.339*	0.097 ^{n.s.}
	2005				
	2004/2005				
YOF	2004		0.613 ^{***}	0.203 ^{n.s.}	0.009 ^{n.s.}
	2005				
	2004/2005				
CF	2004		0.216 ^{n.s.}	0.584 ^{***}	-0.593 ^{***}
	2005				
	2004/2005				
OOF	2004	Glu	0.213 ^{n.s.}	0.203 ^{n.s.}	0.057 ^{n.s.}
	2005				
	2004/2005				
YOF	2004		0.480 ^{**}	0.302 ^{n.s.}	-0.297 ^{n.s.}
	2005				
	2004/2005				
CF	2004		0.435 ^{**}	0.601 ^{***}	-0.622 ^{***}
	2005				
	2004/2005				

^a Level of significance: * P < 0.05, ** P < 0.01, *** P < 0.001, n.s. not significant

In the literature no clear responses of correlation coefficients between the enzyme activities of acid-phosphatase and β -glucosidase to the pH-value were found. Ekenler and Tabatabai (2003b) found negative correlations and Klose and Tabatabai (2002b) found positive correlations and Criquet et al. (2004) found no significant correlation between the soil pH and the activity of acid-phosphatase at all. For β -glucosidase positive correlations (Ekenler and Tabatabai, 2003a; Fugger, 1999) as well no significant correlations (Ekenler and Tabatabai, 2003a) to the pH-value were found.

Between the conventional and organic managed soils only weak changes in pH could be found in two years of field experiments. Values of soil pH remained within the range for optimal nutrient availability in the field and laboratory rainfall experiments. The results obtained at the experiments were supported from earlier findings of Criquet et al. (2004) who stated that pH variations were sometimes too low to influence the activities of acid-phosphatase. For β -glucosidase the same hypothesis as for acid-phosphatase is valid. Melero et al. (2006) promotes the finding that soil pH was in general not different between conventional and organic management systems and Acosta-Martinez et al. (2003a) as well found no particular pH-value related to soil management. As shown by Mäder et al. (2002b) the pH in the organically managed sites was slightly higher than in conventionally managed sites.

5.1.9 Soil temperature and soil moisture

The environmental conditions such as soil temperature and soil moisture content showed in general no significant correlations to the enzyme activity of acid-phosphatase and β -glucosidase in the field experiment (Table 32).

Table 32 Correlation coefficients (R)^a between acid-phosphatase as well as β -glucosidase and soil temperature, soil moisture as well as precipitation in the field experiment

site	year	enzyme	temp			moisture		
			2004	2005	2004/2005	2004	2005	2004/2005
OOF	2004	Pho	0.510**			0.327 ^{n.s.}		
	2005			0.282 ^{n.s.}			0.039 ^{n.s.}	
	2004/2005				0.249 ^{n.s.}			0.120 ^{n.s.}
YOF	2004		0.330*			0.454**		
	2005			0.205 ^{n.s.}			0.066 ^{n.s.}	
	2004/2005				0.264 ^{n.s.}			0.117 ^{n.s.}
CF	2004		0.286 ^{n.s.}			0.409**		
	2005			0.630***			0.390*	
	2004/2005				0.383*			0.062 ^{n.s.}
OOF	2004	Glu	0.416**			0.305 ^{n.s.}		
	2005			0.104 ^{n.s.}			0.213 ^{n.s.}	
	2004/2005				0.011 ^{n.s.}			0.260 ^{n.s.}
YOF	2004		0.552***			0.044 ^{n.s.}		
	2005			0.038 ^{n.s.}			0.022 ^{n.s.}	
	2004/2005				0.184 ^{n.s.}			0.005 ^{n.s.}
CF	2004		0.016 ^{n.s.}			0.492**		
	2005			0.279 ^{n.s.}			0.064 ^{n.s.}	
	2004/2005				0.124 ^{n.s.}			0.142 ^{n.s.}

^a Level of significance: * P < 0.05, ** P < 0.01, *** P < 0.001, n.s. not significant

The temperatures showed at the organically managed sites in 2004 as well as at the conventionally managed site in 2005 a positive significant correlation coefficient to the enzyme activity. Criquet et al. (2004) found positive correlations between the activity of acid-phosphatase and the moisture content as well as negative correlations to the litter temperature. In addition McClaugherty and Linkins (1990), Melero et al. (2006) and Schneider et al. (2001) stated that the major limiting factors for microorganisms are physical and chemical conditions such as temperature and water content. The soil moisture content directly affects the activity of microorganisms. The microbial activity in soils is optimal at a soil water pressure of -0.01 MPa and decreases as the soil becomes either waterlogged or dries (Paul and Clark, 1989). Tisdall et al. (1978) showed that the soil dryness severely restricts microbial activity and therefore has the same effect as soil sterilization. In contrast Fansler et al. (2005) showed only little transformations of β -glucosidase activity due to different water contents as well. Bandick and Dick (1999) reported that β -glucosidase activity varied little in relation to the soil moisture content in similar systems. In addition Schneider et al. (2001) mentioned that the temperature affects the enzyme activity and Dinkelaker and Marschner (1992), Tarafdar and Marschner (1994) and Tarafdar (1988) showed that higher soil temperatures in association with root activity caused a release of acid-phosphatase from plants to the rhizosphere. Harrison and Pearce (1979) did not show any significant correlation between phosphatase activities and environmental factors including temperature and soil moisture.

5.2 Discussion of dynamic effects in the field experiment

In the last chapters the influence of the well established (OOF) and recently established organic farming site (YOF) as well as of the conventional farming management (CF) to biotic and abiotic parameters are discussed. Furthermore the correlation coefficients of the enzyme activities to acid-phosphatase and β -glucosidase are shown and discussed. This analysis reveals that some factors such as Corg, Cmic and the Cmic/Corg ratio are more correlated to the enzyme activities than nitrogen, C/N ratio and pH-value as well as the soil temperature and soil moisture. However to understand the whole dynamic changes at the two organic and one conventional farming site the dynamic changes of acid-phosphatase and β -glucosidase are discussed in regard to the dynamic changes of Cmic and Corg as well as in combination with the management practices.

5.2.1 Fertilizer influence on dynamic effects at the organically and conventionally managed sites

Phosphate fertilizer (P_2O_5) was applied to the OOF site in spring 2004 while the CF site was fertilized with liquid manure. The CF site was in addition fertilized with liquid manure in spring and fall of 2005. The YOF site was not fertilized in any form of P (Fig. 87, Fig. 88, Fig. 89).

The OOF and CF site were not subject to sampling in spring 2004 because the fertilization had taken place 14 days prior to initiative experimenting. The liquid manure application in early February 2005 showed no consequence directly after application, because the liquid manure remained on the snow layer. After thawing the manure reached the soil surface and decreased the enzyme activity and the microbial carbon content. In fall 2005 the liquid manure showed 2 days after application no influence on the enzyme activity, but it decreased in the following weeks. This reduce in fall 2005 could be a result of liquid manure application, but it can be forced by other tillage practices such as plowing, sowing and pesticide treatment which occurred only a few days after manure application. In general tillage practices (such as plowing) were conducted after liquid manure application because the incorporation of liquid manure has been shown to be an effective strategy to reduce P losses through runoff (Bundy et al., 2001; Little et al., 2005). In general the fertilization with phosphorus consistently suppresses phosphatase activity (Clarholm, 1993; Haynes and Swift, 1988), and concentrations of available nutrients often negatively correlate with the activities of nutrient releasing enzymes (Chróst, 1991; Mendes et al., 1999; Sinsabaugh and Moorhead, 1994). However Schneider et al. (2001) found no differences in acid-phosphatase activity between fertilized and unfertilized plots. Conversely, when available nutrients are scarce, microbes can produce enzymes to mobilize resources from complex sources (Harder and Dijkhuizen, 1983; Koch, 1985). Deficiency of P is generally cited as the reason for increased phosphatase activity in the rhizosphere (Tabatabai, 1994; Tadano et al., 1993; Tarafdar and Marschner, 1994; Yadav and Tarafdar, 2001). Häussling and Marschner (1989) and Tadano et al. (1993) also showed that without P fertilization plant roots had higher phosphatase activity on their surfaces in order to compensate for lower soil available P by higher hydrolysis of organic P esters, which could be a reason for higher activities at the organic rather than at the conventional management system. After liquid manure fertilization the enzyme activity of acid-phosphatase increased in spring 2005. In fall 2005 liquid manure application was accompanied by other tillage operations and could therefore not be separately analyzed.

At the CF site mineral N fertilizer in form of urea (CH_4N_2O) was applied in spring 2004 as well as in spring and summer 2005. At the organically managed sites no N fertilization was conducted. However as the N fertilization was accompanied at the CF site by other tillage operations the impact of each measure on enzyme activity could not be separated. In

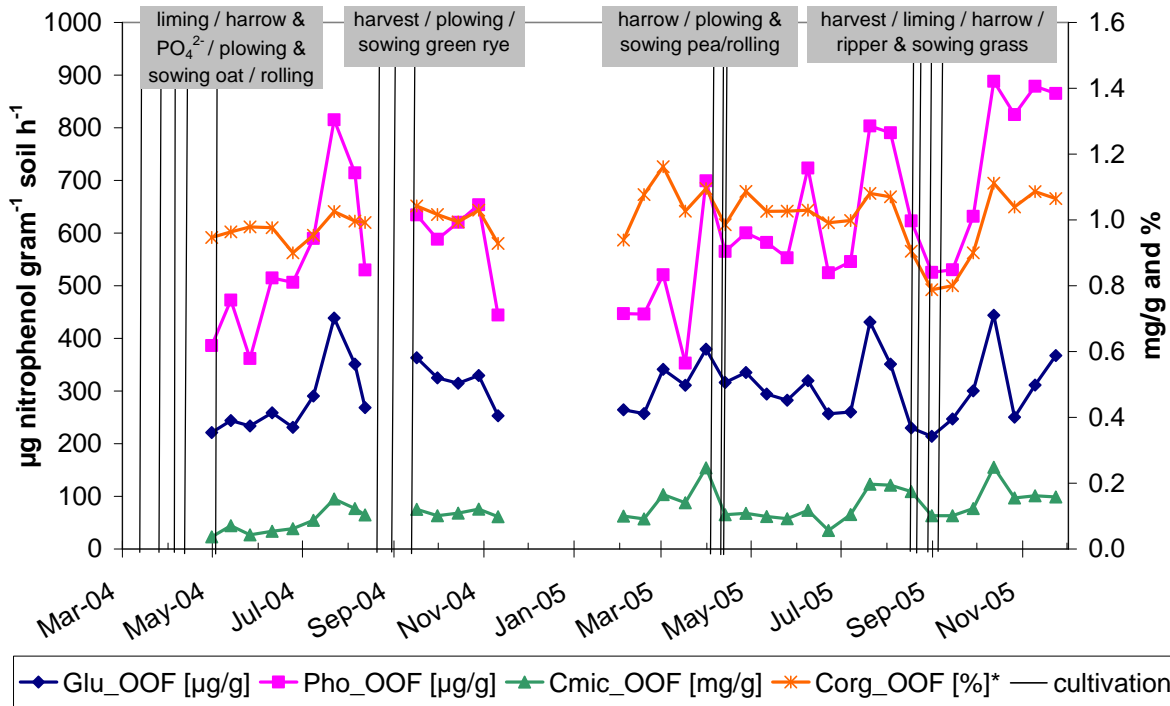
general N fertilization can have significant effects on microbial biomass and enzyme activity through its impact on soil pH (Deng et al., 2000; Moore, et al., 2000; Klose et al., 1999; Klose and Tabatabai, 2000; Knight and Dick, 2004; Motta et al., 2002; Tabatabai, et al., 1992). Reduced microbial activity can be a response of mineral N fertilization which affects enzyme production (Schimel and Weintraub, 2003). Dodor and Tabatabai (2005) showed an effect of N-fertilization in a four year crop rotation for an Iowa (USA) soil but no significant influence on a two year crop rotation. Dodor and Tabatabai (2003) indicated that N fertilization affected the activity of acid-phosphatase in two years on one site. On another site the N fertilization did not affect activities of the acid-phosphatase in Iowa soils. Kirchner et al. (1993) reported higher acid-phosphatase and β -glucosidase activities after N fertilization in comparison to unfertilized soil.

At the CF site inorganic N fertilizers were used in 2004 and 2005, but the effect to the microbial biomass could not be clearly stated because the activity increased as well decreased after N application. These findings were comparable to other studies on the effect of inorganic N fertilizers of soil biological properties which also showed contradictory results. Some researchers have reported increases in the size of microbial biomass (Fraser et al., 1994; Omay et al., 1997), whereas others have shown the opposite (McAndrew and Malhi, 1992; Ladd et al., 1994) or no influence to Cmic content (Moore et al., 2000).

The Old Organic, Young Organic as well as the Conventional farming sites were limed in fall 2005. In general liming leads to increased adsorption of applied phosphate (Haynes and Swift, 1985) and, consequently, to reduced levels of extractable phosphate. Rogasik et al. (2004) showed that lime application in large amounts reduces the soil carbon pool. Acosta-Martinez and Tabatabai (2000b) found changes in enzyme activities due to lime application as well and Haynes and Swift (1988) reported a decrease of acid-phosphatase activity after liming. At all three sites the lime application was accompanied by other tillage operations and could therefore not be evaluated.

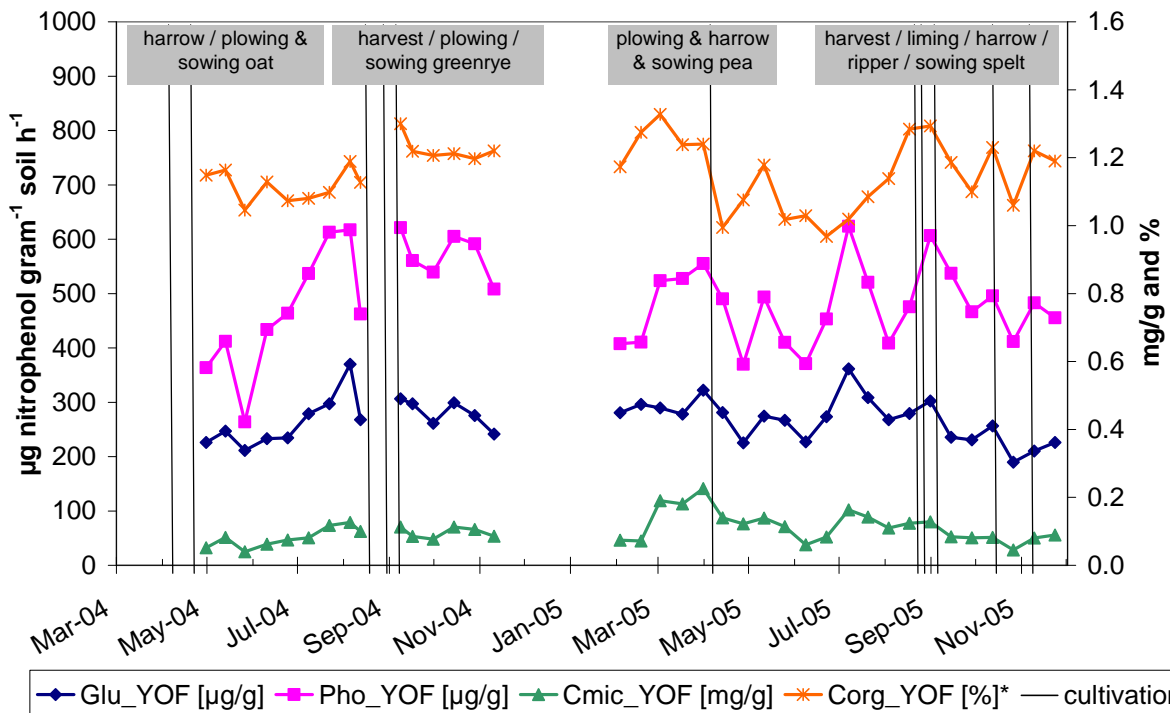
5.2.2 Enzyme dynamic effects at the organic and conventional farming sites

To analyze the dynamic changes of acid-phosphatase and β -glucosidase at the OOF, YOF and CF sites it is necessary that the enzyme activities are shown in combination with the Corg and Cmic content. This combination is chosen due to the high significant correlation coefficients between these parameters. Furthermore the cultivation practices during two years of field experiment are integrated in the figure (Fig. 87, Fig. 88, Fig. 89).



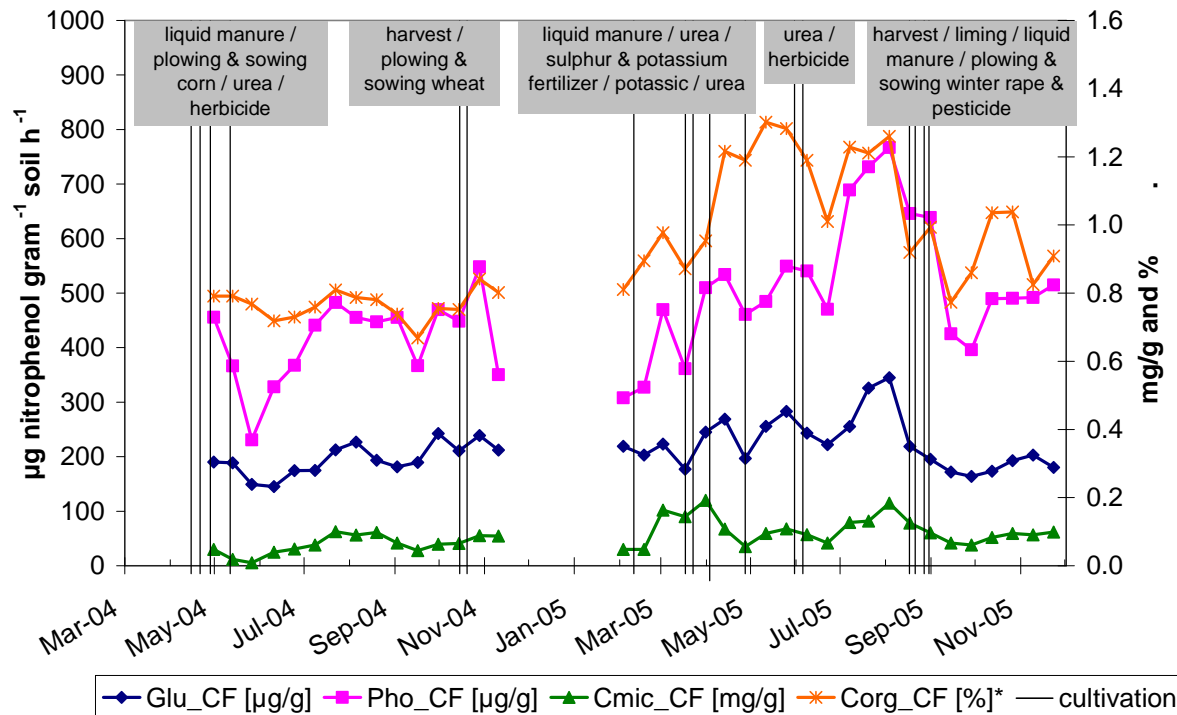
* Variant to the previous description of Corg in mg/g the % scale was used to combine Corg and Cmic at the second Y-axis with the enzyme activity at the first Y-axis

Fig. 87 Activity of β -glucosidase (Glu), acid-phosphatase (Pho), microbial carbon content (Cmic) and organic carbon content (Corg) as well as cultivation practices at the OOF site in 2004 and 2005



* Variant to the previous description of Corg in mg/g the % scale was used to combine Corg and Cmic at the second Y-axis with the enzyme activity at the first Y-axis

Fig. 88 Activity of β -glucosidase (Glu), acid-phosphatase (Pho), microbial carbon content (Cmic) and organic carbon content (Corg) as well as cultivation practices at the YOF site in 2004 and 2005



* Variant to the previous description of Corg in mg/g the % scale was used to combine Corg and Cmic at the second Y-axis with the enzyme activity at the first Y-axis

Fig. 89 Activity of β -glucosidase (Glu), acid-phosphatase (Pho), microbial carbon content (Cmic) and organic carbon content (Corg) as well as cultivation practices at the CF site in 2004 and 2005

At the organic farming sites (OOF, YOF) the effects of microbial carbon, organic carbon and the enzyme activities and effects are comparable which could be due to similar cultivation practices and crops. Subsequent to the spring cultivation in 2004 the microbial carbon showed only a weak influence, but beginning in May showed an increasing trend until the middle of July 2004. This general increase of microbial carbon could be a result of greater root density which resulted in greater microbial activity in the root rhizosphere (Moore et al., 2000; Schinner and Sonnleitner, 1996b). The improved microbial activity supports the enzyme activity of acid-phosphatase and β -glucosidase (George et al., 2002; Grierson and Adams, 2001; Schneider et al., 2001; Schinner and Sonnleitner, 1996b; Tarafdar and Marschner, 1994). In addition Tarafdar and Marschner (1994) showed that high organic matter contents resulted in an increased production of phosphatases of plant origin due to an increase in total root surface area.

Furthermore the plant roots could influence the enzyme activity directly. Dinkelaker and Marschner (1992), Tarafdar and Marschner (1994) as well as Yadav and Tarafdar (2001) showed that the plants start secreting acid-phosphatase as soon as their roots emerged. Schneider et al. (2001) found strong and significant relationships between fine root length density and acid-phosphatase activity. Tabatabai (1994) mentioned that β -glucosidase activity increased as a result of enhanced plant root growth because β -glucosidase was detected in soils, fungi, yeast and plants (Tabatabai, 1994). Another hypothesis could be that

soil tillage practices caused in beneficial soil aeration and therefore in larger decomposition rates of residues (Balota et al., 2003) which caused higher enzyme activities because organic matter is the preferred energy source for microorganisms (Friedel et al., 1996; Klose et al., 1999; Vaughan and Malcolm, 1985). Deng and Tabatabai (1996b) showed that β -glucosidase is the driving force in the decomposition of carbohydrates in soils and the activity of the enzyme is dependent upon available cellulose as substrate.

After mid July 2004 the enzyme activities at the OOF and YOF sites were decreasing until harvest. A possible hypothesis could be that the plant root system from the summer crops is dying and therefore no more acid-phosphatase and β -glucosidase could be produced by plants. Furthermore the soil temperatures rose and the soil moisture contents decreased during this time (Annex 6). This hypothesis was supported from Haynes and Swift (1988) and Paul and Clark (1989) who reported lower enzyme activity rates under low soil moisture contents as well as from Schneider et al. (2001) who showed that the temperature affects the enzyme activity.

Subsequent to fall cultivation 2004 the microbial carbon content, organic carbon content as well the acid-phosphatase and β -glucosidase activities at the OOF and YOF sites showed a decreasing trend until September 2004. This decreasing trend could be explained with the hypothesis that plowing mixes the residues from the surface with the upper soil layer. The increased aeration and soil residue contact promoted the oxidation of soil organic carbon and as a result the organic carbon content decreased (Dolan et al., 2006; Fenton et al., 1999; Haynes, 1999; Melero et al., 2006; Six et al., 1999).

In early February 2005 the values of organic carbon, microbial carbon as well as the enzyme activities were approximately at the same levels as at the last sampling in November 2004. A reason for this pattern was given from Bandick and Dick (1999) as well as from Schinner and Sonnleitner (1996a) who showed that enzyme activities varied only little during winter time because of low temperatures. In early 2005 after the snow thawed the microbial carbon content showed an increasing trend until spring cultivation 2005. A hypothesis for this increase was given from Balota et al. (2003) who showed that rising soil temperatures and favorable soil moisture contents result in higher microbial activity due to the transformation of residues from the microbial pool.

After spring cultivation 2005 at the OOF and YOF sites the microbial carbon, organic carbon content and the enzyme activities showed a stable, respectively a weak decreasing tendency until May but thereafter an enhanced tendency until mid July 2005, after which the contents decreased until harvest. The same behavior at the OOF and YOF site was found in 2004.

After fall cultivation 2005 the microbial carbon, organic carbon, acid-phosphatase and β -glucosidase showed an increased trend at the OOF site until the last sampling at the end of November 2005. This increasing tendency was a result of plants and plant roots. However in contrast to the OOF site the carbon content and the enzyme activities at the YOF site decreased after fall cultivation 2005. Sowing grass at the OOF site in fall 2005 increased the enzyme activities because grass had an increased and earlier root development than spelt.

At the Conventional Farming site (CF) the microbial carbon content as well as the activity of acid-phosphatase and β -glucosidase decreased after herbicide application in spring 2004. A possible hypothesis could be that after herbicide application the microbial community was destructed. The microbial carbon content and the enzyme activities recovered and increased until mid of summer. Thereafter the carbon contents and enzyme activities showed a decreasing trend until mid of September and subsequent again a rising trend until the last sampling. The increasing trend could be explained with enhanced root development as discussed for the organic farming sites and the followed increasing trend with high soil temperatures and low soil moisture contents until mid of September. At the organic farming sites the enzyme activities decreased as well as at the CF site at the same time which supports this finding. Thereafter the temperature decreased and the higher moisture contents resulted in increased microbial activity.

In 2005 the enzyme activities and the microbial carbon content at the CF site showed as well as the organic farming sites nearly the same patterns (discussed above). After herbicide application in June 2005 and September 2005 the same behavior was found as after herbicide application in spring 2004. In the organically managed soils (without any herbicide application) the microbial carbon content dropped in 2005 as well as at the CF site at the same time, which put the influence of herbicide application to the decrease of Cmic into question. According to McLaughlin and Mineau (1995) herbicides reduce the populations of non-target plant and animal species, but in contradiction Lupwayi et al. (1998) found no effect of increased herbicide use under zero tillage and stated furthermore that the effect of herbicide use on soil microbial diversity is not yet solved which was in accordance with the results shown above.

In conclusion the Cmic content and Corg content were in 2004 and 2005 highly correlated with the enzyme activity of acid-phosphatase and β -glucosidase at the organic farming sites as well as at the conventional farming site. These findings indicated a strong linear relationship between the enzyme activities and microbial carbon as well organic carbon. The temperature showed in some cases high positive and significant correlation coefficients to the activities of both enzymes at the OOF, YOF and CF site. The temperature influence was

more pronounced in 2004 than in 2005. The dynamic changes of acid-phosphatase and β -glucosidase at the Old Organic Farming site, Young Organic Farming site and Conventional Farming site were in general pooled results of Cmic, Corg, and temperature dynamics. Other factors such as nitrogen and soil moisture content could influence the enzyme activities under specific conditions as well.

In addition to these findings the enzyme activities of acid-phosphatase, β -glucosidase and the microbial carbon content were at the well established organic farming site (OOF) higher than at the recently established organic farming site (YOF). Both organic farming sites showed furthermore higher values than the conventional farming site (CF). The YOF site could be understood as an interstage between the well established organic farming and the conventional farming. The management system has a considerable influence to the microbial activities as well as to the enzyme activity. The organic carbon content as well as the microbial content has the potential to influence the acid-phosphatase and β -glucosidase significantly. Furthermore these parameters were good indicators to assess changes in management systems.

5.3 Aggregation ratios, biotic and abiotic effects at the soil surface

5.3.1 Aggregation ratio, soil surface crusting, runoff and infiltration

The image analysis was conducted to determine the aggregation ratios at the soil surface. The aggregation ratio was defined as the randomly occurrence of peaks and depressions resulting from soil clods and aggregates at the soil surface. According to this definition the aggregation ratio is comparable to the term "soil surface roughness" because Currance and Lovely (1970) defined also the soil surface roughness as randomly oriented arrangement of soil clods and aggregates.

The image analysis was suitable to determine the aggregation ratio at the soil surface. This method can be used independent of the site and weather conditions. The only constriction was given by the time to mark the aggregates manually. Therefore more research was conducted and this method was modified. The improved method uses digital stereo photogrammetry (bundle block adjustment and image matching techniques) to derive Micro-digital-elevation-models (DEM). The Micro-DEM's were afterwards used to calculate soil surface roughness indices (Marzahn et al., 2007).

The soil structure and aggregation is a key factor for oxygen supply to the root zone and to soil organisms, water infiltration and preventing soil erosion (Franzluebbers, 2002b; Le Bissonnais, 1996; Pinheiro et al., 2004; Youngs and Leeds-Harrison, 1990) and promoting crop production (Langmaack, 1999). In general an aggregated surface will gradually slake and be smoothed by raindrop energy (e.g. Abu Hammad et al., 2006; Loch and Foley, 1994; Moldenhauer and Kemper, 1969). Aggregate stability affects the soil susceptibility to seal formation and according to Le Bissonnais (1996) the tendency of a soil to form a crust. The aggregate breakdown by water is in general a result of physical and physicochemical mechanisms (Levy and Mamedov 2002). These mechanisms are:

- Compression of entrapped air during fast wetting (defined as slaking) (Fohrer, 1991; Kwaad and Múcher, 1994), whereas in general, slaking increases with increasing water tension (Chan and Mullins, 1994)
- Different swelling mechanisms during fast wetting (Boiffin and Monnier, 1999)
- Kinetic energy of raindrops (e.g. Kwaad and Múcher, 1994; McIntyre, 1958a, b; Moldenhauer and Kemper, 1969)
- Physicochemical dispersion due to osmotic stress during wetting with low electrolyte water (Emerson, 1967)

Aggregate breakdown in general causes soil surface sealing and after drying out, surface seals will form crusts (Agassi et al., 1994; Bohl and Roth, 1993; Slattery and Bryan, 1994). The crusting processes are relatively well known and described today (Le Bissonnais et al., 1989). For example Norton (1987), Gimenez et al. (1992), Mualem et al. (1990) as well as Sumner and Stewart (1992) investigated the mechanisms of aggregate breakdown and crust formation by raindrop impact. In the classic papers of Agassi et al. (1981) and McIntyre (1958a) and newer papers of Boiffin and Monnier (1999) as well as Le Bissonnais et al. (1989) the general sequences that lead to crust formation under rainfall were described as the following.

- Primarily: Aggregate breakdown caused by raindrop impact or slaking, particles are not displaced. Water can infiltrate into the soil.
- Secondly: Movement of fine soil particles with the infiltrating water into the upper few millimeters of the soil and clogging the pores beneath the surface
- Thirdly: Displacement and mechanical breakdown of mobilized particles have sealed the surface.

A structural seal consists therefore of two distinct parts: an upper skin attributed to compaction by raindrop impact, and a "washed-in" zone of decreased porosity, as a result of small particles accumulation in the pore system (McIntyre, 1958a; Norton, 1987). However, there is still a considerable debate about "washed-in" layers (Slattery and Bryan, 1994), because other researchers (e.g. Arshad and Mermut, 1988; Bertrand and Sor, 1962) found

that these “washed-in” layers are not significant in seal formations. A physical soil crust is according to Bohl and Roth (1993) and Gicheru et al. (2004) a thin (according to Bergsma (1996) from a few mm to a few cm) compacted layer which is formed at the soil surface and less porous than the immediately underlying soil (Kwaad and Múcher, 1994). Skidmore and Layton (1992) believed that the fine particle fraction of the soil plays a very important role in soil crusting processes and that an increase of finer soil particles increases the crust strength. Drying of the seal and the formation of a crust disrupts the seal. Initially the crust has a high infiltration rate but a strong seal quickly redevelops causing increased runoff and soil loss rates compared with the initial seal (Bradford and Huang, 1994). Soil surface seal properties are mainly responsible for infiltration and runoff (Bohl and Roth, 1993; Bradford and Huang, 1994). The soil surface structure and crusting is one of the main factors controlling runoff and subsequent water erosion in cultivated soils and is also a major threat to sustainable agriculture (Farres, 1987; Le Bissonnais et al., 2005; Lecomte et al., 2001).

Field experiment

In 2004 the initial aggregation ratio at the CF site was comparable to the OOF site, were both sites showed a lower aggregation ratio than at the YOF site. One reason for the higher aggregation ratio at the YOF site could be due to the fact that rolling the soil surface was only conducted at the OOF site and not at the YOF site. Pinheiro et al. (2004) revealed that mechanical tillage caused in a reduction of soil aggregates. Another reason could be that the clay content at the YOF site is higher than at the OOF site. In any way the initial aggregation at the three sites was a random roughness.

Already in June 2004 the soil surface at the CF management showed initial crust signs whereas the soil surfaces of the organic managed sites (OOF, YOF) were well aggregated and showed only weak and negligible crusting signs. Due to additional rainfall the aggregation ratio declined at all sites, but soil surface sealing was more pronounced at the conventional than at the organic farming sites. In August 2004 the soil surface of the CF site was totally sealed whereas the organic sites showed only first visible crusting signs. At the organically farming sites the image analysis stopped in August 2004 due to harvest and the following tillage practices. At the conventional farming site the image analysis was conducted till October due to the longer vegetation period of maize and began showing a weak new aggregation ratio in September (Fig. 90).

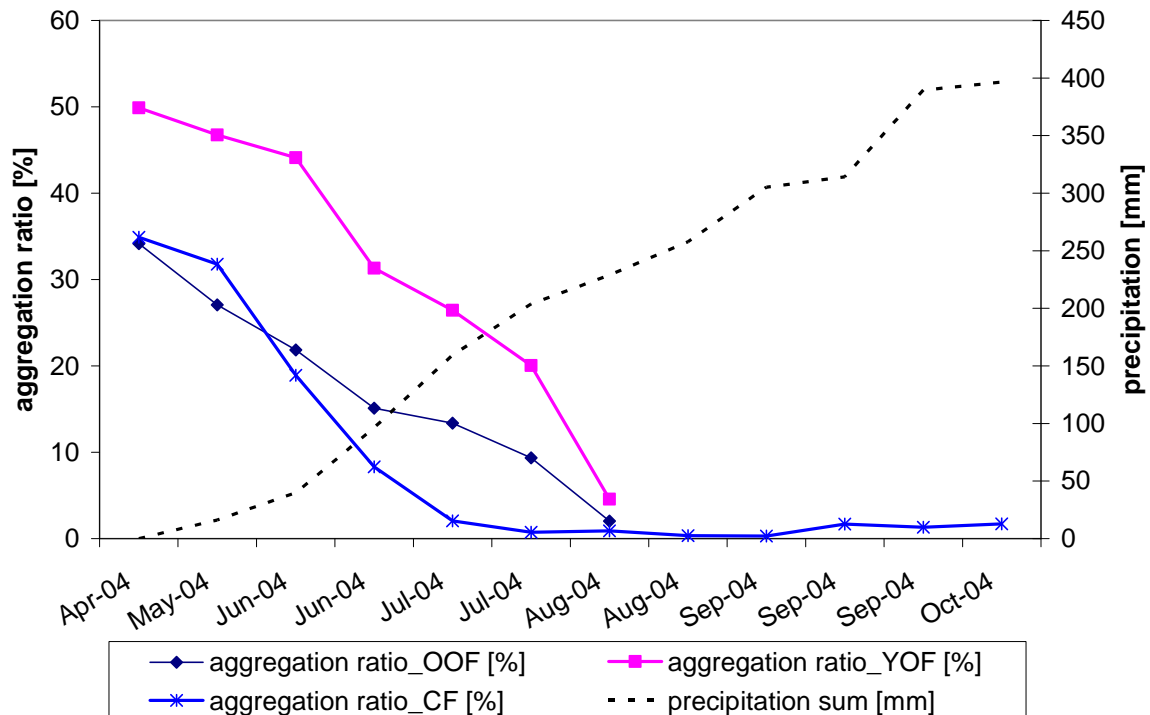


Fig. 90 Aggregation ratios (%) at the OOF, YOF and CF soil surfaces during the field experiment 2004

In Table 33 the aggregation ratio change in combination with the precipitation is shown. The aggregation ratio at the OOF site decreased 7.1 %, at the YOF and CF site only 3.1 % after 16.1 mm precipitation. After additional precipitation of 23.8 mm the aggregation ratio decreased at the CF site 12.8 %, at the OOF site 7.1 % and at the YOF site 3.1 %. In general the precipitation resulted in a lower aggregation ratio at each site (with an exception in September-2004 at the CF site). Therefore negative and significant correlation coefficients were found between the aggregation ratio and the precipitation sum at the OOF site ($R=-0.958^{***}$), YOF site ($R=-0.974^{***}$) and CF site ($R=-0.818^{***}$). The precipitation resulted in different aggregation ratio changes at the OOF, YOF and CF sites. A hypothesis for the increased aggregation ratio in September-2004 at the CF site is that the activity of the soil fauna destructs the soil surface sealing. The faunal activity was not measured, but the visual assessment showed that a lot of earthworms holes existed at the soil surface as well as new small aggregates were build up during the “re-aggregation” period.

Table 33 Aggregation ratio change at the OOF, YOF and CF site during the field experiment 2004

date	precipitation [mm]	aggregation ratio OOF [%]	aggregation ratio YOF [%]	aggregation ratio CF [%]
4/30/2004	0.0	initial aggregation	initial aggregation	initial aggregation
5/13/2004	16.1	-7.1	-3.1	-3.1
6/10/2004	23.8	-5.2	-2.6	-12.8
6/24/2004	56.4	-6.7	-12.8	-10.6
7/8/2004	63.0	-1.7	-4.9	-6.3
7/22/2004	44.4	-4.0	-6.4	-1.3
8/5/2004	25.1	-7.3	-15.5	+0.2
8/19/2004	29.0			-0.6
9/2/2004	47.4			±0.0
9/16/2004	9.0			+1.4
9/30/2004	75.3			-0.4
10/14/2004	6.9			0.4

In 2005 the aggregation ratio after spring tillage practices (including plowing, harrowing and sowing at both sites and additional rolling at the OOF site) showed at the first image analysis that the Old Organic Farming site was comparable to the Young Organic Farming site. Due to sowing winter wheat at the CF site the soil surface was already sealed in April (Fig. 91). The aggregation ratio decrease at the OOF and YOF site was as well as in 2004 a result of the precipitation sum. The linear regression model showed negative significant correlations between the aggregation ratio and the precipitation sum at the OOF site ($R=-0.742^{***}$), YOF site ($R=-0.847^{***}$) and positive correlation at the CF site ($R=0.595^{***}$). The positive correlation coefficient at the CF site is related to the fact that the soil surface was at the beginning of the image analysis totally sealed (aggregation ratio=0.8 %) and that the aggregation ratio increased during the field experiment 2005. The aggregation ratio declined at the OOF and YOF site with each rainfall event but was more pronounced at the OOF site than at the YOF site. Both organically managed plots showed first crusting signs in June.

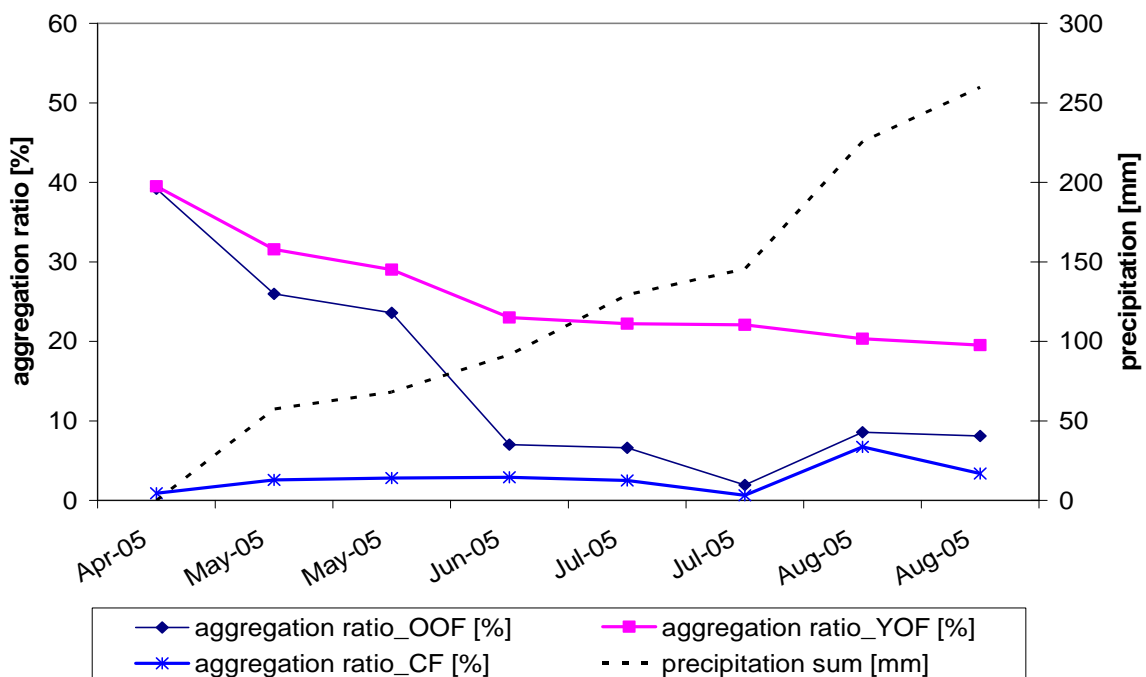


Fig. 91 Aggregation ratios (%) at the OOF, YOF and CF soil surfaces during the field experiment 2005

At 20-July-2005 the aggregation ratio declined at the YOF and CF sites may be due to high rainfall intensity (12.1 mm/h) and a total rainfall of 26 mm directly before the images were taken which caused in leveled aggregates at the surface. The soil surface at the YOF site was not influenced because the images were taken prior of this rainfall. At 03-August-2005 the aggregation ratio at the OOF site increased 6.6 % and at the CF site 6.1 %. This increase could be a result of 80 mm precipitation between 20-July and 03-August, but the aggregation ratio at the YOF site decreased 1.7 % (Table 34). This increase could be a result of the biological activity (e.g. earthworms) which influenced the soil surface at the sealed OOF and CF surface more than at the better aggregated YOF surface. Another possible reason could be that the effect of large aggregates at the YOF soil surface is stronger than new aggregation patterns. In general, the aggregation ratio at the CF site increased with increasing precipitation sum. This pattern is a result of already sealed conditions in April-2005 at the CF site because winter wheat was sown in October-2004 and the soil surface aggregates during the winter time were not protected against rainfall. This pattern showed a general favor for the organically farming sites (with winter cover crops) in comparison to the conventional managed (without winter cover crops).

Table 34 Aggregation ratio change at the OOF, YOF and CF site during the field experiment 2005

date	precipitation [mm]	aggregation ratio OOF [%]	aggregation ratio YOF [%]	aggregation ratio CF [%]
4/13/2005	0.0	initial aggregation	initial aggregation	initial aggregation
5/11/2005	57.5	-13.2	-7.9	+1.7
5/25/2005	10.6	-2.4	-2.6	+0.2
6/8/2005	23.4	-16.6	-6.0	+0.1
7/7/2005	37.8	-0.4	-0.8	-0.4
7/20/2005	16.3	-4.7	-0.1	-1.9
8/3/2005	80.0	+6.6	-1.8	+6.1
8/17/2005	34.1	-0.5	-0.8	-3.4

In addition the analysis of variance (ANOVA) showed for 2004 that the aggregation ratio (absolute) at the OOF and CF sites were significantly different to the YOF site (Annex 7). The differences to the YOF site were related to the higher initial aggregation ratio as a result of different tillage practices. Due to different aggregation levels at the first sampling in 2005 of the conventional and organically farming sites the ANOVA was not carried out.

Rainfall experiment

In addition to the field experiment the laboratory rainfall experiment with intermittent rainfall events was conducted to investigate the aggregate ratio (microtopography) at the soil surface, susceptibility to soil surface sealing, runoff under controlled conditions as well as the influence of the soil surface character on infiltration. The assessment of soil susceptibility to runoff in the field is often expensive or time-consuming. At the microplot scale ($\leq 1 \text{ m}^2$), evaluation of runoff often involves rainfall simulation, which is a rather sophisticated method

(Barthes and Roose, 2002). Rainfall simulations are widely used for the quantification of runoff processes (Seeger, 2006). Schneider et al. (1999) and Niebes et al. (2001) analyzed runoff pathways as well as the influence of different management systems on runoff generation. According to (Bryan and Poesen, 1989) and Gómez and Nearing, (2005) rainfall simulations under laboratory conditions are suitable to identify singular parameters influencing runoff processes. Laboratory rainfall simulations on micro plot scale ($\approx 1 \text{ m}^2$) are predestined to quantify infiltration and runoff generation and are valuable for giving a clear view on the processes occurring on the site and their intensities (Seeger, 2006).

The results from the conducted rainfall experiment provide a crosslink to the field experiment. The intermittent rainfall characteristic reflects the natural field conditions better than a continuous rainfall event, because the natural cycle of wetting and drying of the soil surface is taken into account. The dried soil surface in the rainfall experiment is therefore comparable to a soil surface dried by wind and sun after a rainfall event under natural conditions (Fohrer et al., 1999).

Some researchers stated that runoff and erosion data measured under simulated rainfall lack the correlation to natural data (Barthes and Roose, 2002; Le Bissonnais and Arrouays, 1997). But Abu Hammad et al. (2006) showed that the kinetic rain energy is a key factor to runoff and erosion and were in his experiments similar to that of natural rainfall. Bohl and Roth (1993) revealed in addition that the conductance of soil surface crusts formed under natural and simulated rainfall were not significantly different. According to the rainfall intensity (15 mm/h), drop range and drop velocity the findings in the laboratory rainfall experiment were without any restrictions comparable to runoff field experiments. In the past, simulated rainfall experiments were mostly conducted with sieved soil samples. Therefore the development of runoff remains questionable (Reichert and Norton, 1994; Le Bissonnais and Arrouays, 1997). Due to the placement of natural aggregates at the soil surface the results were transferable to field experiments.

The aggregation ratio dynamics at the conventional (CF) and organic (OOF, YOF) soils were shown in association with the precipitation sum and the kinetic energy (Fig. 92).

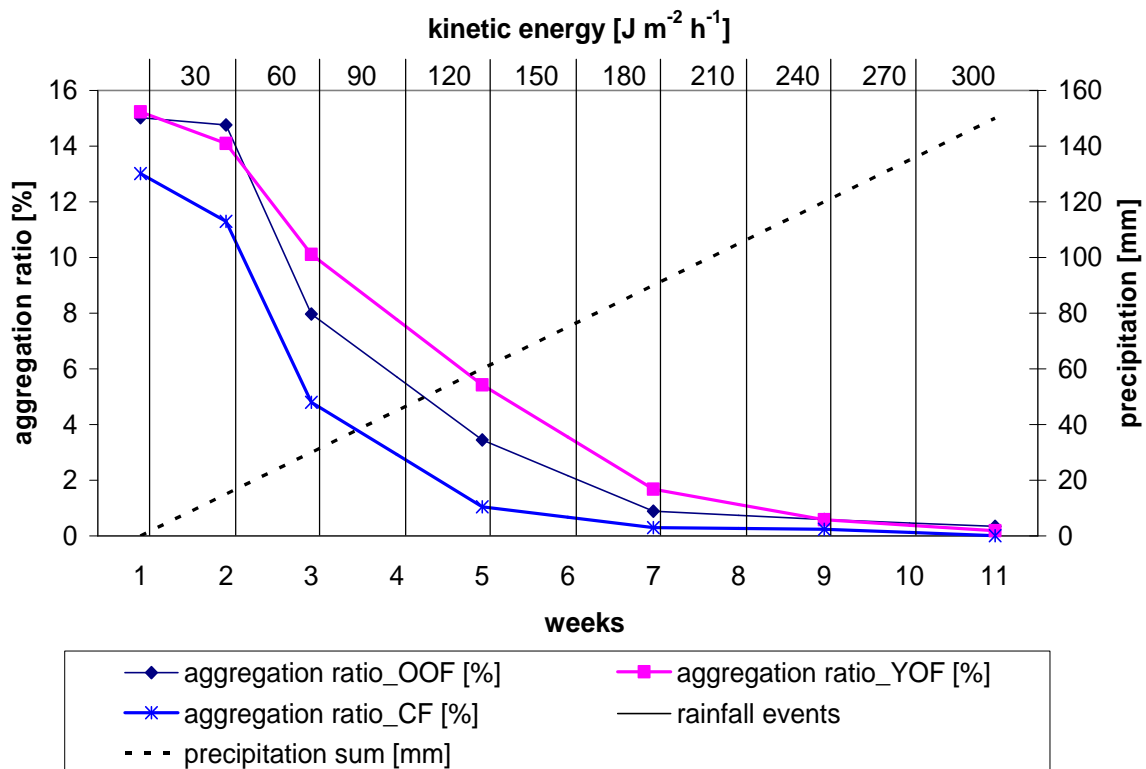


Fig. 92 Aggregation ratios (%) of the OOF, YOF and CF soils at the laboratory rainfall experiment in 2004 and 2005

The initial aggregation ratio at the OOF, YOF and CF sites were in a range of 13.0 % to 15.2 % whereby nearly the same aggregate size distribution was given. Therefore the following dynamic processes at the soil surface were comparable, because rainfall characteristics and rainfall duration were the same at all sites. The aggregation ratio declined after the first rainfall event only on a small scale but showed after the second rainfall event the highest reduction. After the fourth rainfall event the aggregation ratio decreased with increased numbers of rainfall events (Table 35). This pattern is probably a result of high initial aggregation and decreasing aggregate fractions which can destruct from rainfall drops. However the aggregation ratio in the rainfall experiment declined with increased precipitation. Ben-Hur et al. (1989) as well as Ghezzehei and Or (2000) stated that after tillage the soil structure disintegrates as a result of rainfall and considerably alters soil hydraulic properties. The surface seals at the OOF, YOF and CF soils became more established with an increasing number of wetting and drying cycles. This finding is in accordance with results of Hardy et al. (1983). In addition Wells et al. (2003) stated that raindrop impact causes clogging the micropores and subsequent to soil surface sealing.

Table 35 Aggregation ratio change at the OOF, YOF and CF site during the rainfall experiment

rainfall event	precipitation [mm]	E_{kin} [$J m^{-2} h^{-1}$]	aggregation ratio OOF [%]	aggregation ratio YOF [%]	aggregation ratio CF [%]
0	0	0	initial aggregation	initial aggregation	initial aggregation
1	15	30	-0.3	-1.1	-1.7
2	30	60	-6.8	-4.0	-6.5
4	60	120	-4.5	-4.7	-3.7
6	90	180	-2.6	-3.7	-0.7
8	120	240	-0.3	-1.1	-0.1
10	150	300	-0.3	-0.4	-0.2

High negative and significant correlation coefficients were found at all sites between the aggregation ratio and the cumulative rainfall (OOF soil, $R=-0.906^{***}$; YOF soil, $R=-0.954^{***}$; CF soil, $R=-0.857^{***}$), but the ANOVA showed that the aggregation ratio change at the OOF, YOF and CF soil is in general not significantly different (Annex 8). Therefore the effect of the precipitation sum is stronger than the influence of the management system to the aggregation ratio. But however under comparable conditions (same precipitation, same kinetic energy, and same initial aggregation ratio) the aggregation ratio declined during the first rainfall events at the conventional farming soil more than at the organic farming soil, and showed earlier crusting signs than the organic soil as well. This finding was supported from previous aggregate stability tests at the same sites. The analysis of aggregate stability indicated that the OOF and YOF sites were not significantly different. However, the aggregate stability at both organic farming sites was significantly different to the conventional farming site (Schwarz, 2005). The ΔGMD values showed that the aggregate stability at the CF site is lower than at OOF and YOF site (Table 36).

Table 36 ΔGMD at the OOF, YOF and CF sites

	OOF	YOF	CF
ΔGMD	1.0	1.1	1.4

Lower values indicate a higher aggregate stability;
Schwarz (2005)

The decreased aggregation ratio during subsequent rainstorms in the laboratory rainfall experiment was comparable to the results at the field experiment 2004. But in the field experiment 2005 the aggregates at the YOF soil surface were less destroyed than at the OOF site. Fohrer et al. (1999) stated that subsequent rainstorm experiments are more comparable to natural conditions than single rainstorm experiments. But in general the transferability of data reached under simulated rainfall conditions to natural conditions in the field experiment was given with constrictions. Under natural condition the rainfall intensity as well as the aggregate water content is very variable. The aggregate water content determines aggregate breakdown mechanism, the breakdown products and the resulting surface sealing (Le Bissonnais et al., 1989). Moister aggregates have a lower hydraulic gradient and therefore a lower wetting velocity which results in lower aggregate destruction

(Panabokke and Quirk, 1957). Wetting of dry aggregates leads to air slaking and therefore to intensive crushing of aggregates (Fohrer et al., 1999). The results obtained under simulated rainfall conditions can classify dynamic changes between different soils.

Runoff and infiltration characteristics

During the first rainfall event the total precipitation water infiltrated into the soil, because the soil surface showed no crusting signs. Therefore the water tension 3 cm below the surface decreased at all three sites with nearly the same patterns and the water content 30 cm below the surface increased (Fig. 93; Fig. 94). After the first rainfall event (total precipitation: 15 mm) the aggregation ratio decreased at all three sites only on a small scale, but at the CF soil initial crusting signs were visible. A reason for this behavior was given from Levy and Mamedov (2002) who mentioned that the raindrop impact energy of the first rainfall event was not enough to disintegrate aggregates and lead to soil surface sealing. During the second rainfall event the water tension at the CF and YOF site decreased slowly which resulted in first runoff pattern at these sites. In comparison, at the OOF site the rainfall water infiltrated completely and no runoff occurred. Burwell and Larson (1969) have shown highly significant correlation of infiltration capacities prior to the start of runoff with a roughness index and that differences can only occur due to the nature of the sealed or crusted layer formed at the soil surface. After the second rainfall (total precipitation: 30 mm) the aggregation ratio decreased more intensively than after the first rainfall event and the soil surface of the organically managed soils showed initial crusting appearance whereas the CF soil was visually totally crusted.

In the third rainfall event the previous surface crusting resulted in decreased water infiltration. This is in accordance to Usón and Poch (2000) who mentioned that soil crusts reduce the infiltration rate and increase runoff, because soil crusts have a lower percentage of planar pores (Norton, 1987). This is probably due to rapid structural deterioration caused by slaking and dispersion (Guzha, 2004). Additional Chappell et al. (1999) revealed a strong relevance of aggregate stability with soil erosion and runoff. The runoff at the CF site started earlier than at the YOF site due to lower aggregation ratio at the soil surface. The OOF site showed only at the end of the third rainfall cycle first runoff patterns. After the third rainfall event (total precipitation: 45 mm) the soil surfaces of the organically and conventionally managed soils were visually crusted. The soil surface crusting resulted in decreased infiltrations rates. The runoff started at first at the CF soil with the highest runoff rate, then at the YOF soil with medium runoff and at last at the OOF soil with the lowest runoff rate. This runoff pattern did not change until the last rainfall was conducted (Fig. 93).

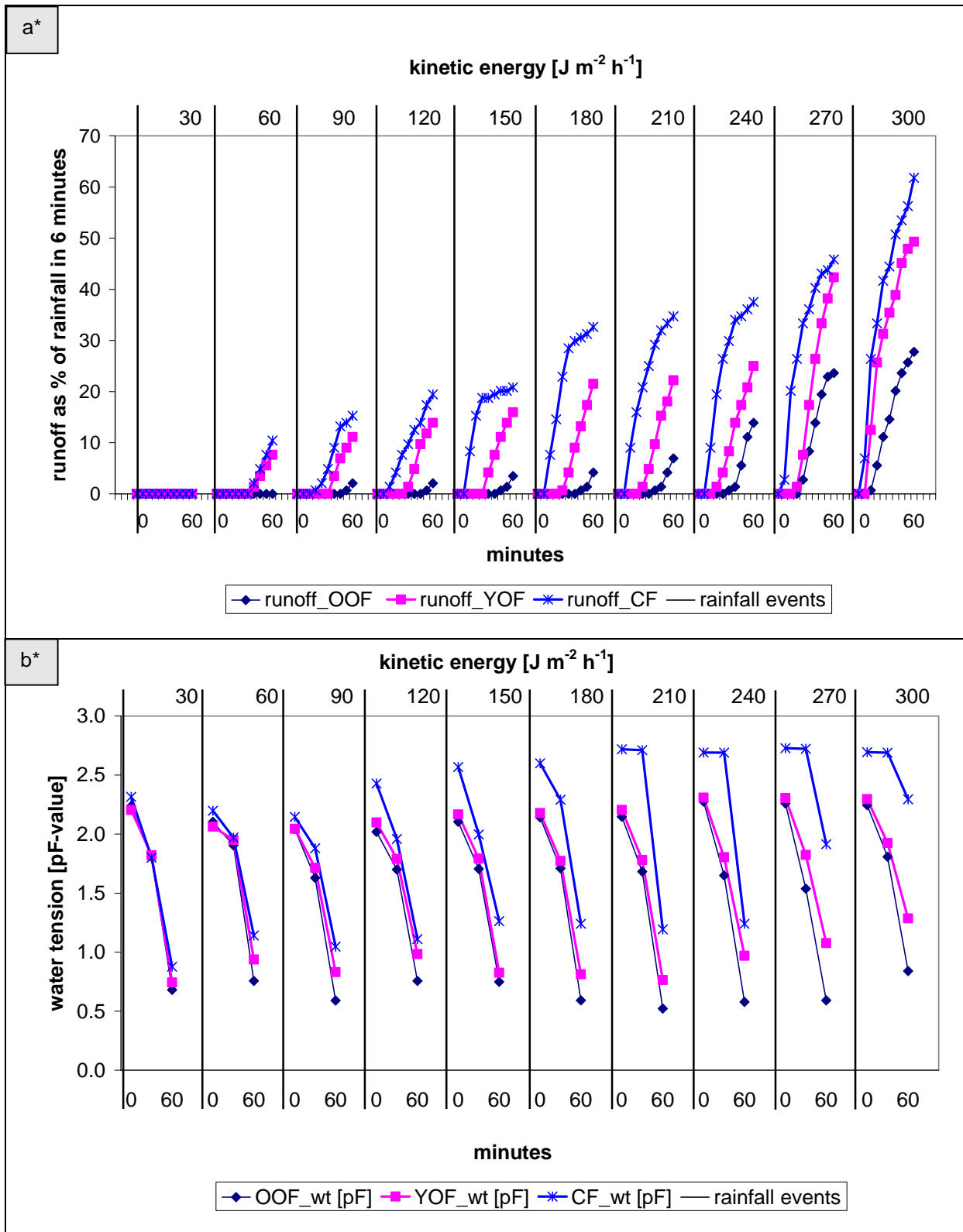


Fig. 93 Runoff as % of rainfall in 6 minute intervals during each 60 minutes rainfall event (a), water tension 3 cm below the surface in 30 minutes intervals during each 60 minutes rainfall event (b)

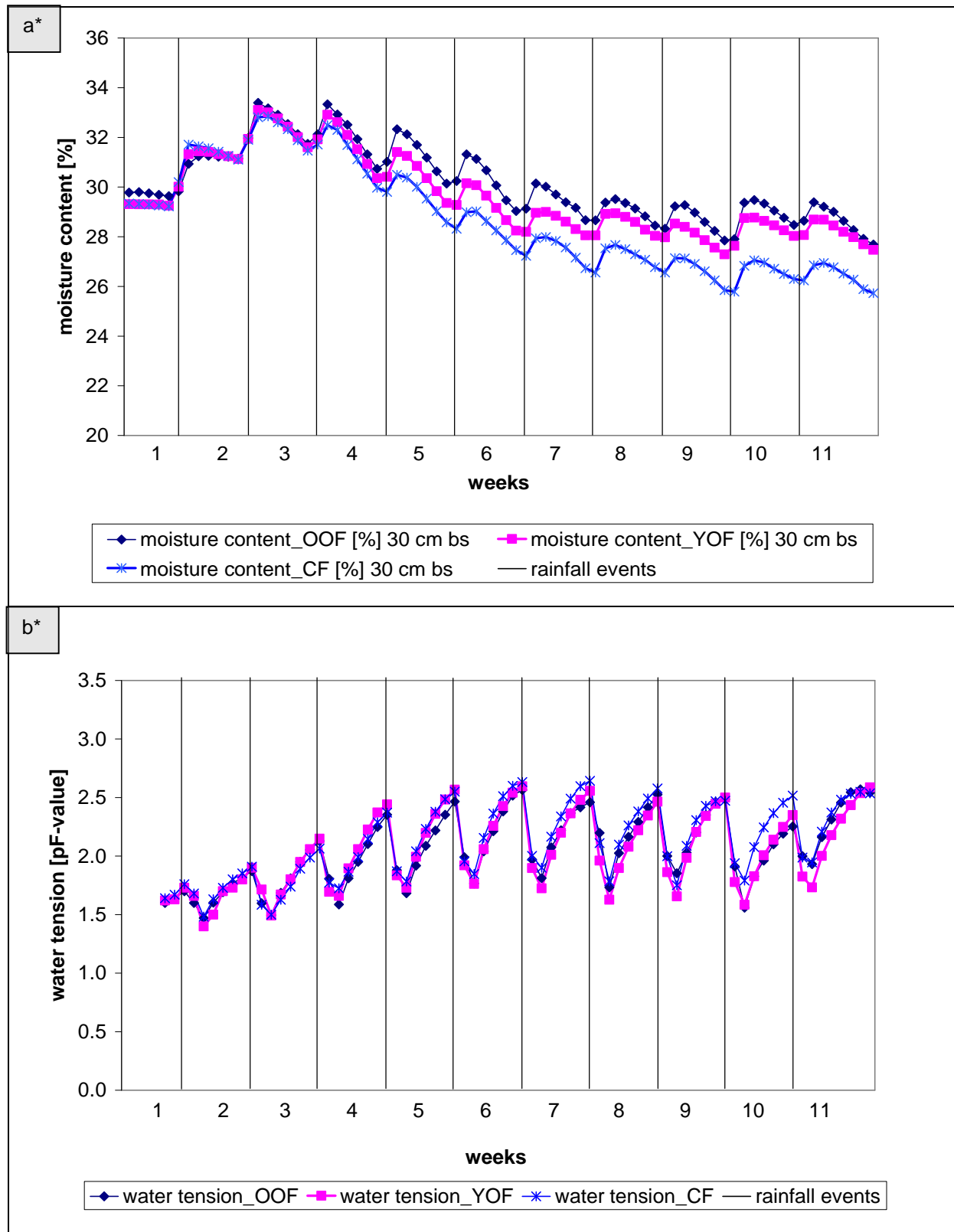


Fig. 94 Moisture content 30 cm below the soil surface during 11 weeks of the rainfall experiment (a) and water tension 3 cm below the soil surface during 11 weeks of the rainfall experiment (b)

Wu and Fan (2002) found positive correlations between the raindrop intensity and the compactness, thickness and bulk density of physical soil crust, because raindrop impact provided high-energy pulses which dislodged and displaced soil particles from the soil

surface in the splash process. Also Proffitt et al. (1993) as well as Wakindiki and Ben-Hur (2002) found that surface runoff increased as a result of the crust formation at the soil surface with increasing cumulative precipitation. The soil surface crusting resulted in higher pF-values 3 cm below the surface of the conventionally managed soil compared to the organically managed soils. The infiltration process is important in the hydrologic cycle, because it determines the soil water, runoff and soil erosion. The decreased infiltration rate during the rainstorm resulted mainly from the aggregate disintegration and subsequent seal formation at the soil surface (Morin et al., 1981; Assouline, 2004). Ben-Hur and Letey (1989) stated that the permeability of the soil is affected by seal formation. Fohrer (1995) showed that soil surface sealings have a low hydraulic conductivity. The decreased hydraulic conductivity and therefore the increased runoff rate during the rainfall events resulted in seal formation and lower water contents 30 cm below the soil surface. These findings were in accordance to Morin et al. (1981) as well as Falayi and Bouma (1975) who found variations between tillage managements when they determined the matric potential beneath the soil surface seal.

In general the soil sealing was characterized by changes in soil infiltration rate and runoff volume. These findings were in accordance with Fohrer et al. (1999) who showed under laboratory rainfall conditions that the infiltration rate decreased with increasing cumulative rainfall energy. Morin et al. (1981) stated that seal formation reduces the infiltration rate, thus increasing runoff. This finding was supported from Fox et al. (1998a, b), Le Bissonnais et al. (2005), Levy and Mamedov (2002), Usón and Poch (2000) who showed that soil surface crusting has a major impact on water infiltration. Due to the rainfall experimental design the soil surface was dry when the next rainfall was conducted. Dry surface conditions enhance air slaking of aggregates and the small aggregate breakdown products form subsequently a seal with a low hydraulic conductivity (Fohrer, 1995). With decreasing soil surface aggregation the runoff increased and the infiltration rate decreased. Fohrer et al. (1999) found similar patterns and stated that the steepness of infiltration decrease is proportional to the degree of presealing. Reichert and Norton (1994) as well as Le Bissonnais and Arrouays (1997) reported negative relationships between aggregate stability of sieved soil samples and soil susceptibility to runoff and erosion. Franzluebbbers (2002b) showed in addition that the stability of soil aggregates from a depth of 0 - 3 cm was linear related with the infiltration rate. Roth et al. (1987), Bajracharya et al. (1992) reported relationships between aggregate stability and soil susceptibility to erosion from field experiments, under simulated rainfall on microplots or under natural rainfall conditions. Results of Barthes and Roose (2002) confirmed that topsoil aggregate stability was closely and negatively related to soil susceptibility to runoff in the field at different scales, in different locations and contexts.

The aggregate stability analysis of Schwarz (2005) showed that the CF soil had the lowest aggregate stability followed by the OOF and YOF site. Le Bissonnais (1996) stated that lower aggregate stability at the soil surface tend to higher susceptibility of seal formation. The runoff data however showed that the runoff at the CF soil is higher than at the YOF soil. The OOF soil showed the lowest susceptibility for soil surface runoff. Therefore the aggregate stability indices were conferrable with exceptions for the organic farming soil, because the YOF had higher aggregate stability than the OOF soil but the YOF soil had higher runoff rates than the OOF soil. A reason for this behavior was given from Van Dijk et al. (1996) who showed under simulated rainfall conditions in the field (silty loess) that runoff was better correlated with the degree of surface slaking, assessed by visual comparisons, than with the kinetic energy of rainfall or aggregate stability. Furthermore Levy and Mamedov (2002) found in experiments of a kaolinitic southeastern US soil that aggregate stability data correlated well with clay content but not with organic matter content.

The soil surfaces of the conventionally and organically managed soils were totally sealed and crusted after 45 mm total precipitation, but the sealed soil surfaces resulted in different runoff behaviors and soil water contents (3 cm below the surface) during the rainfall events at the three management systems. The ANOVA showed that the runoff at the Old Organic farming site was significantly different to the Conventional Farming system (Annex 8). Furthermore the water tension 3 cm below the soil surface was significantly different (after 30 and 60 minutes) between the organic farming sites and the conventional farming site (Annex 9). These results show that the organically farming sites, if sealed, infiltrate more rainfall than conventional farming sites although they showed the same soil surface behavior. A possible reason for this pattern was given from Pagliai et al. (2004) and Zhang et al. (2006) who mentioned that the soil crust at the organic farming system contains a few large pores that provide continuous, vertical transmission pathways that discharge water and hence thereby cause less runoff. Le Bissonnais et al. (1989) and Fohrer (1995) stated that coarser breakdown products lead to more permeable seals. However the organic farming soils had greater potential to infiltrate more rainfall and the soil erosion hazard was reduced which is a benefit for long-term productivity of organically managed systems (Zhang et al., 2006). Furthermore Martens and Frankenberger (1992) showed that increased organic matter improved water infiltration due to stimulation of soil microbial activity and development of more stable aggregates.

Before the first rainfall event the water content was at a constant level (29.6 %) and rose after the first rainfall event to 31.1 % and after the second to 33.4 %. Nearly the same infiltration pattern and soil moisture contents 30 cm bs were reached up to the third rainfall event, which indicate that the soil surface sealing at the OOF, YOF and CF soil was not different. After the third rainfall event the soil moisture content at the OOF soil was higher than at the YOF soil. The CF soil showed the lowest soil moisture content. Between the rainfall events (with exception of the first rainfall event) the water content decreased (due to the suction plates which were installed at the bottom of each soil box) and increased after each rainfall event. Generally the water content during the whole experimental period ranged between 27.8 % and 33.4 % with a decreasing tendency during the rainfall experiment. After the first rainfall event started, the infiltration front reached a depth of 30 cm after approx. 60 minutes at the OOF, YOF and CF soil. At the tenth rainfall event the infiltrated water reached a soil depth of 30 cm after approx. 90 minutes at the OOF and YOF soil and at the CF after 150 minutes. The soil moisture 30 cm bs increased for two days after each rainfall event, thereafter the soil moisture decreased until the next rainfall event. Fohrer et al. (1999) as well investigated the infiltration capacity during rainfall events (30 mm intensity) of a gleyeric luvisol and stated that after 90 minutes the water front arrive a depth of 30 cm.

The results from the rainfall experiment provide a suitable crosslink to the field observations. Furthermore the rainfall experiment indicates the relationship between soil surface roughness, runoff, and infiltration. Consequently the conversion from conventionally to organically farming showed a high influence to the runoff formation, therefore the organically management system is favorable to protect the soil against runoff and erosion. The hypothesis of Morin et al. (1981) and Lado et al. (2004) that the soil infiltration rate, surface runoff respectively, can be used as an index to characterize seal formation and its properties is not valid if different management systems are compared. But if only one site is considered the lower the infiltration rate the more developed is the soil surface crust.

5.3.2 Influence of biotic and abiotic factors to the aggregation ratio

In the rainfall experiment the enzyme activity of acid-phosphatase and β -glucosidase showed negative and significant correlations to the aggregation ratio (range between $R=-0.396^*$ and $R=-0.950^{***}$) at the soil surface, as well as no significant correlations. Allison and Jastrow (2006) hypothesized that minerals and aggregates could enhance C stability by physically preventing the enzyme degradation of C compounds. Soil aggregation can limit enzymatic decomposition by preventing microbes and enzymes from making contact with substrates inside the aggregates (Sollins et al., 1993). Such restriction might cause carbon to build up within aggregates. Furthermore Allison and Jastrow (2006) predicted that increases

in soil aggregation and C concentration would be accompanied by a reduction of enzyme activities within soil aggregates. If however the enzymes as well as organic carbon is stabilized within soil minerals the enzymes could coexist to organic carbon without degrading them (Zimmermann et al., 2004). The amount and type of carbon compounds that will be lost during aggregate breakdown and turnover is determined through the compartmentalization of organic carbon and the linked aggregate-enzyme complex. During aggregate turnover the enzymes which are responsible for carbon degradation will play a key role in defining the labile carbon and as a consequence the aggregate-enzyme complex is essential for storage of carbon (Fansler et al., 2005). In addition Gupta and Germida (1988) and Miller and Dick (1995a, b) concluded that macroaggregates present an environment for enzyme activity and microbial biomass (Table 37).

The random roughness (aggregation ratio) of tilled soils is according to Allmaras et al. (1966) and Guzha (2004) an important factor for infiltration, evaporation and runoff control. Although tillage is used to increase soil porosity, it is a short-term solution that has negative consequences on surface soil structural stability, surface residue accumulation, and surface soil organic carbon. These critical features control water infiltration and subsequently water transmission and water storage in soil (Franzluebbers, 2002b). With increasing rainfall sum the aggregation ratio declined at all three sites in 2004 and 2005 (with an exception for CF 2005), because rainfall played an important role in the formation of physical soil crust (Le Bissonnais et al., 1998a, b; Wu and Fan, 2002) and was significant and linear related with rainfall energy (Bohl and Roth, 1993). In addition Guzha (2004) showed that the random roughness declined with time due to the crumbling of the soil clods as a result of raindrop impact. The pronounced soil surface sealing at the conventional site was probably attributed to a deterioration of structural stability resulting from continuous cropping (Smith et al., 2006) and therefore the decreased aggregation ratio could be due to slaking and breaking of soil clods as a result of raindrop energy (Guzha, 2004).

In the field experiment 2004 and 2005 the Corg content was only negative and significant correlated ($P < 0.05$) with the aggregation ratio at the OOF (Table 37). Green et al. (2006) and Kay and Angers (1999) found strong links between aggregate stability and organic matter content and Fansler et al. (2005) stated in addition that organic matter accumulation and storage is coupled with the aggregate stability. Herrick et al. (2001), Pinheiro et al. (2004) and Tisdall and Oades (1982) revealed that organic matter is one of the main agents favoring soil aggregation, but Levy and Mamedov (2002) found no significant correlations between aggregate stability and organic matter content. In general the YOF and the CF sites showed no significant correlation coefficients to the organic carbon content. A reason for this behavior was given from Piccolo et al. (1999) and Chenu et al. (2000) who revealed that not

only the amount of organic matter but also its composition is of importance for the stabilization of soil aggregates. Consequently, in some cases high organic matter content is not accompanied by high structural stability (Sarah, 2006).

In the field and rainfall experiments the Conventional Farming site showed earlier and more pronounced soil crusting signs than the Organic Farming sites (OOF, YOF). Green et al. (2006) revealed that soil aggregation and stability can change with tillage management. No-till practices allow continued aggregation over a long period of time, whereas conventional tillage disrupts the aggregation process. At the organic farming sites the aggregation ratio decreased with increasing rainfall sum but the decrease was more pronounced at the OOF site than at the YOF site, may be due to higher clay content at the YOF site which resulted in a higher aggregate stability. It is well documented that the clay content is known to affect the aggregate stability (Cerdeira, 1998; Levy and Mamedov, 2002). However Ben-Hur et al. (1985) found that in soils containing more than 20 % clay content the clay fraction acts as a cementing material, stabilizing soil aggregates against raindrop impact and therefore preventing the soil against crust formation. On the other hand, in soils containing less than 20 % clay content, the clay acts as a substrate for crust formation, decreasing the steady state hydraulic conductivity of the crust. In addition Awadhwal and Thierstein (1985) showed that soils which have high clay and sand content and low organic matter content were prone to surface sealing, crusting and runoff.

Table 37 Correlation coefficients (R)^a between the aggregation ratio and biotic and abiotic parameters^b at the OOF, YOF and CF site for 2004, 2005 and 2004/2005

variable	Aggregation ratio			Aggregation ratio			Aggregation ratio		
	OOF			YOF			CF		
	2004	2005	2004/ 2005	2004	2005	2004/ 2005	2004	2005	2004/ 2005
Pho	-0.864***	-0.620***	-0.715***	-0.950***	0.093 ^{n.s.}	-0.569***	-0.396*	0.378*	-0.325*
Glu	-0.725***	-0.218 ^{n.s.}	-0.461**	-0.922***	-0.048 ^{n.s.}	-0.669***	-0.363*	0.274 ^{n.s.}	-0.339*
Corg	-0.398*	-0.299*	-0.318*	-0.026 ^{n.s.}	-0.390*	0.098 ^{n.s.}	0.229 ^{n.s.}	-0.007 ^{n.s.}	0.242 ^{n.s.}
Cmic	-0.808***	-0.633***	-0.645***	-0.891***	0.308*	-0.475**	-0.683***	0.663***	-0.490**
precip. sum	-0.958***	-0.742***	-0.832***	-0.974***	-0.847***	-0.827***	-0.818***	0.595***	-0.543**

^a Level of significance: * P < 0.05, ** P < 0.01, *** P < 0.001, n.s. not significant

^b Acid-phosphatase (Pho), β -glucosidase (Glu), organic carbon content (Corg), microbial carbon content (Cmic) and precipitation sum (precip. sum)

The microbial carbon content as well as the enzyme activity showed in general negative and significant correlations in the field (Table 37). This result was supported by Tabatabai (1994) who stated that the microbial population is the major source of soil enzymes. In addition Bearden and Petersen (2000), Guggenberger et al. (1999) as well as Tisdall and Oades (1982) stated that plant roots, fungal hyphae and microbial exudates are important for aggregate stability, because they are binding agents and source of organic material to soil aggregates. Therefore it could be well understood that the enzyme activity which derives from roots are important for aggregate stability. The microbial population controls soil processes. Jastrow et al. (1996) and Six et al. (1999) showed that increased microbial activity can lead to increased soil aggregation. Changes in aggregate stability are believed to provide a long-term indication of changes in organic matter quantity and quality (Lynch and Bragg, 1985). Alguacil et al. (2005) revealed that the soil microbial activity is linked to the aggregate stability and Mäder et al. (2002b) found high positive correlations between aggregate stability and microbial biomass.

It could be concluded that the precipitation sum is one of the major controlling factors for aggregate stability and susceptibility to soil surface sealing and crusting. This hypothesis was supported from high negative and significant correlations (2004, 2005) between the aggregation ratio and the precipitation sum. Schwarz (2005) found in previous analysis at the same sites that the aggregate stability at the organic farming sites was significantly higher than at the conventionally farming site. Furthermore high significant correlation coefficients but as well as no significant correlation coefficients were found between the aggregation ratio and enzyme activities as well as to the microbial carbon. Therefore no clear trend could be stated and the enzyme activity of acid-phosphatase and of β -glucosidase is linear correlated with the aggregation ratio. Consequently more investigations are needed to confirm this hypothesis.

5.4 Conclusion

In the upper three centimeters of the soil surface the enzyme activities of acid-phosphatase and β -glucosidase as well as the microbial carbon content were significantly influenced by the management systems as well as of the date of conversion to organic farming. In general the mean square values of acid-phosphatase, β -glucosidase and microbial carbon were at the well established organic farming site (OOF) higher than at the recently established organic farming site (YOF). Both organic managed sites showed higher enzyme activities and higher microbial carbon contents than the conventional farming site (CF). Therefore the Young Organic Farming site could be understood as an interstage between the conventional farming system and the well established organic farming system.

Between the enzyme activities of acid-phosphatase and β -glucosidase high and significant correlation coefficients were found to the microbial carbon as well as to the organic carbon. These findings indicated a strong linear relationship between the enzyme activities and microbial carbon as well as organic carbon. However the temperature showed in some cases high positive and significant correlation coefficients to the activities of both enzymes at the OOF, YOF and CF site. The dynamic changes of acid-phosphatase and β -glucosidase at the Old Organic Farming site, Young Organic Farming site and Conventional Farming site were in general pooled results of Cmic, Corg, and temperature dynamics. But other factors such as nitrogen and soil moisture content could as well influence the enzyme activities under specific conditions.

The biotic indicators such as acid-phosphatase, β -glucosidase and microbial carbon were good indicators to analyze differences between management systems. They were also appropriate to reveal short time differences between conventional management system and the date of conversion from conventional to organic farming. But however to classify the results it is very important to analyze these parameters for a longer period of time because the dynamic changes in between season were intense.

In addition to the analysis of biotic and abiotic parameters the soil surface was considered in the field under natural and therefore not controllable conditions as well as in the laboratory rainfall experiment under controlled conditions. Martens and Frankenberger (1992) showed that increased organic matter improved water infiltration due to stimulation of soil microbial activity and development of more stable aggregates. However in the conducted experiments high significant correlation coefficients and no significant correlation coefficients were found between the aggregation ratio and the enzyme activities as well as to the Cmic content. Therefore no clear trend could be stated. Consequently more investigations are needed to

confirm the hypothesis that the enzyme activities of acid-phosphatase and β -glucosidase influence the aggregation ratio at the soil surface as well as the susceptibility for soil surface crusting.

In the field as well in the rainfall experiment the precipitation sum was the major reason for a aggregation ratio decrease at the soil surface and therefore to the susceptibility for soil surface crusting. In the rainfall experiment the aggregation ratio declined at the Conventional Farming site more and showed earlier soil crusting signs than at the Organic Farming sites. The runoff during the rainfall experiments at the CF site was higher than at the YOF site. The OOF site showed the lowest runoff. The organic farming soils infiltrated as well more rainfall water than the conventional farming sites although they showed the same aggregation ratio at the soil surface during the last four rainfall events.

Therefore the recently established organic farming site (OOF) could be understood as interstage between the well established organic farming site (OOF) and the conventional farming site (CF). Due to these findings the hypothesis of Morin et al. (1981) and Lado et al. (2004) that the soil infiltration rate, respectively surface runoff, can be used as an index to characterize seal formation and its properties is not valid if different management systems are compared. But if only one site is considered the lower the infiltration rate the more developed is the soil surface crust.

6 Summary

In agricultural areas the soil surface presents in general a vital interface that receives different impacts due to the tillage and residue management. In northern Germany one well established organic farming site (OOF), one recently established organic farming site (YOF) and one conventional farming site (CF) were selected to identify management effects to biotic and abiotic parameters in the rhizosphere. Extensive field experimental analyses under non controlled environmental conditions as well as laboratory rainfall experiments under controlled environmental conditions were conducted. In the field experiment large dynamic changes of the biotic and abiotic parameters were found. In general the experimental data showed that the enzyme activities, microbial carbon, organic carbon and the C_{mic}/C_{org} ratio were significantly affected by the date of conversion from conventional to organic farming management and from the conventional management system. In general the biotic and abiotic parameters at the OOF site were higher than at the YOF site. Both organic managed sites showed higher values than the CF site.

Additional to the field experiment a rainfall experiment was conducted to analyze the management effects of soil surface aggregation and crusting to runoff and infiltration. The experimental data received from the rainfall experiment showed that the soil surface crusting process at the conventional soils started earlier than at the organic soils. While the soil surface of the conventionally and organically managed soils were similarly sealed the well established organic farming management (OOF) showed lower runoff rates than the recently established organic farming management (YOF). Both organic farming managements showed lower surface runoff rates and a higher water infiltration capacity than the conventional management (CF).

Consequently the recently established organic farming site (YOF) could be understood as an interstage between the conventional farming system (CF) and the well established organic farming system (OOF). The conversion from conventional farming to organic farming results in a greater potential to infiltrate rainfall and lower runoff rates. These findings indicate furthermore that the activities of acid-phosphatase and β -glucosidase can be used to identify differences between land use managements. They are also appropriate to find short time differences between the dates of conversion from conventional to organic farming.

7 Zusammenfassung

Die Bodenoberfläche von landwirtschaftlich genutzten Böden wird durch unterschiedliche Bewirtschaftung stark beeinflusst. Um den Effekt ökologischer Bewirtschaftung auf biotische und abiotische Faktoren der Bodenoberfläche erforschen zu können, wurden in Norddeutschland zwei ökologisch und eine konventionell bewirtschaftete Fläche ausgewählt. Im Einzelnen handelte es sich dabei um eine Old Organic Farming Fläche (OOF), die seit 1994 von konventionell auf organische Bewirtschaftungsweise umgestellt wurde und um die Young Organic Farming Fläche (YOF), die seit 2001 organisch bewirtschaftet wird. Weiterhin wurde eine konventionell bewirtschaftete Fläche (CF) untersucht. Die Analysen wurden einerseits im Freiland unter den natürlichen Bedingungen, als auch im Labor unter kontrollierten Umgebungsbedingungen durchgeführt. In dem zweijährigen Feldexperiment wurden dynamische Effekte der biotischen und abiotischen Parameter auf allen Versuchsfeldern entdeckt. Anhand statistischer Analysen konnte festgestellt werden, dass die Enzymaktivitäten der sauren Phosphatase und β -Glucosidase, sowie der Gehalt an mikrobiellem und organischem Kohlenstoff signifikant von der konventionellen als auch von der organischen Bewirtschaftungsweise beeinflusst wurden. In den Experimenten wurden höhere biotische Aktivitäten und abiotische Werte auf dem OOF Schlag gefunden als auf dem YOF Schlag. Beide organische Schläge zeigten höhere Aktivitäten und Gehalte als unter konventioneller Bewirtschaftung. Im Beregnungsexperiment wurde zusätzlich zu den abiotischen und biotischen Feldanalysen noch der Oberflächenabfluss und die Infiltrationsleistung analysiert. Dabei zeigte sich, dass es unter kontrollierten Bedingungen nur zu geringen Schwankungen der mikrobiellen Aktivität kam, trotz allem aber höhere Enzymaktivitäten in dem OOF als in dem YOF Boden gefunden wurden. Beide organische Böden zeigten ebenso höhere Werte als der konventionelle Boden. Die Analyse der Oberflächenaggregation zeigte, dass der CF Boden schneller verschlämmt als die Böden der organischen Bewirtschaftung obwohl die Niederschlagsmenge nicht variierte. Weiterhin konnte festgestellt werden, dass auf dem OOF Boden weniger Oberflächenabfluss entstand als auf dem YOF Boden. Der CF Boden zeigte den höchsten Oberflächenabfluss und die geringste Infiltrationsleistung, obwohl alle drei Böden visuell gleiche Verkrustungserscheinungen aufwiesen. Somit wurde gezeigt, dass durch eine Veränderung der Bewirtschaftungsweise ein positiver Effekt auf die Infiltrationsleistung ausgeübt werden kann, wodurch die Gefahr von Bodenerosion verringert wird. Anhand der Ergebnisse kann die seit 2001 organisch bewirtschaftete Fläche (YOF) als Zwischenstufe der seit 1994 organisch bewirtschafteten Fläche (OOF) und der konventionellen Bewirtschaftung (CF) angesehen werden. Ebenso zeigte sich, dass die Analyse der β -Glucosidase und der sauren Phosphatase geeignet ist Unterschiede zwischen Bewirtschaftungsweisen zu erfassen.

8 References

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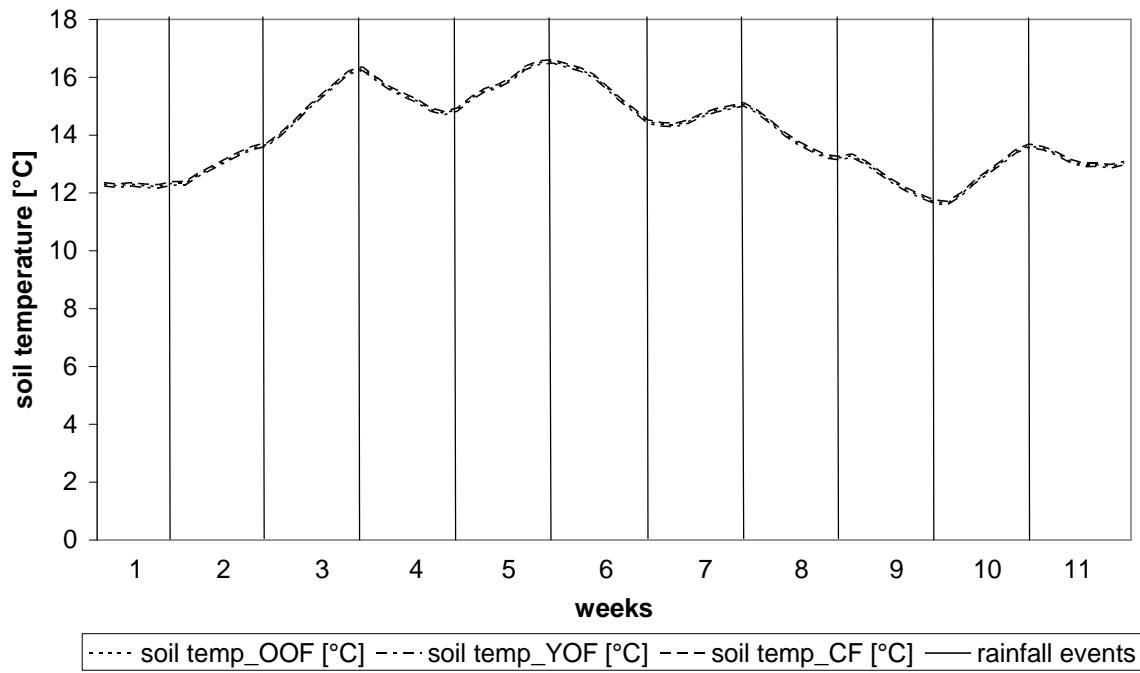
9 Annex

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Annex 1 General standard for plant production of the "Naturland" Association for Organic Agriculture for the Old and Young Organic Farming sites

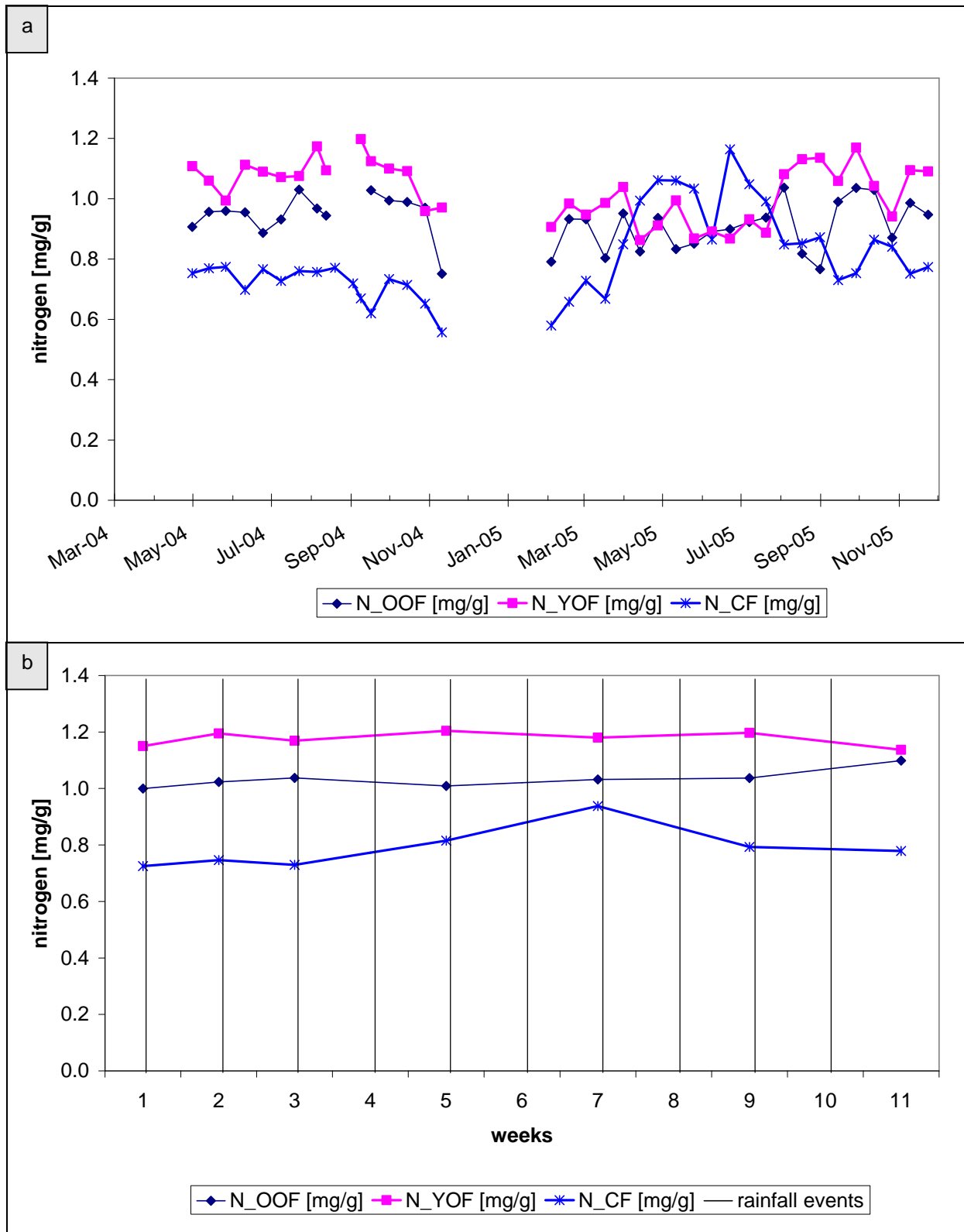
Old Organic Farming site (OOF)	Young Organic Farming site (YOF)
<p>1. Humus management and fertilization</p> <ul style="list-style-type: none"> • "The humus balance has to be at least at equilibrium within the margin of varied crop rotation. For permanent crops, this has to be guaranteed by adequate measures such as undersown crops, catch crops, or permanent ground coverage." • "Biodegradable matter of microbe, vegetable or animal origin forms the basis of fertilization." • "Given the importance of a balanced lime level for topsoil stability, for the structure and thus the fertility of the soil, and because of acid absorption through precipitation, special attention has to be paid to an adequate lime supply with respect to the area." 	
<p>2. Pest, disease and weed control</p> <ul style="list-style-type: none"> • "To encourage healthy plants, prophylactic measures such as crop rotation appropriate to the site in question, tillage, humus management and fertilization, the choice of appropriate stand densities as well as the selection of healthy and resistant plants and seeds is the most important considerations." • "The use of synthetic chemical substances is prohibited." • "Weeds are, as accompanying plants of crops and as the habitat of fauna, a prerequisite for a varied community of species." 	
<p>4. Tillage</p> <ul style="list-style-type: none"> • "The tillage process shall be such as to conserve the natural layers of the soil structure. This is done by employing the appropriate machinery. Special attention must be paid to the adequate humidity of the soil during the tilling process." 	
<p>5. Soil and water conservation</p> <ul style="list-style-type: none"> • "Measures suitable to avoid the erosion of soil must be taken. Excessive exploitation and exhaustion of water resources is not allowed." 	
<p>6. Crop production</p> <ul style="list-style-type: none"> • "Crop rotation is the basis of agricultural plant production on which the biological cycle in organic agriculture is founded." • "During crop rotation, winter and summer crops should complement each other in their effects to prevent the negative developments of monoculture." • "Special attention has to be paid to ensuring sufficiently long periods between the cultivation of the same kind of crops." • "The washing out of nutrients must be prevented by suitable cultivation measures (e.g. undergrowth, plowing rotas commensurate with local conditions)." 	

<http://www.naturland.de>, date of access: 04.09.2006.

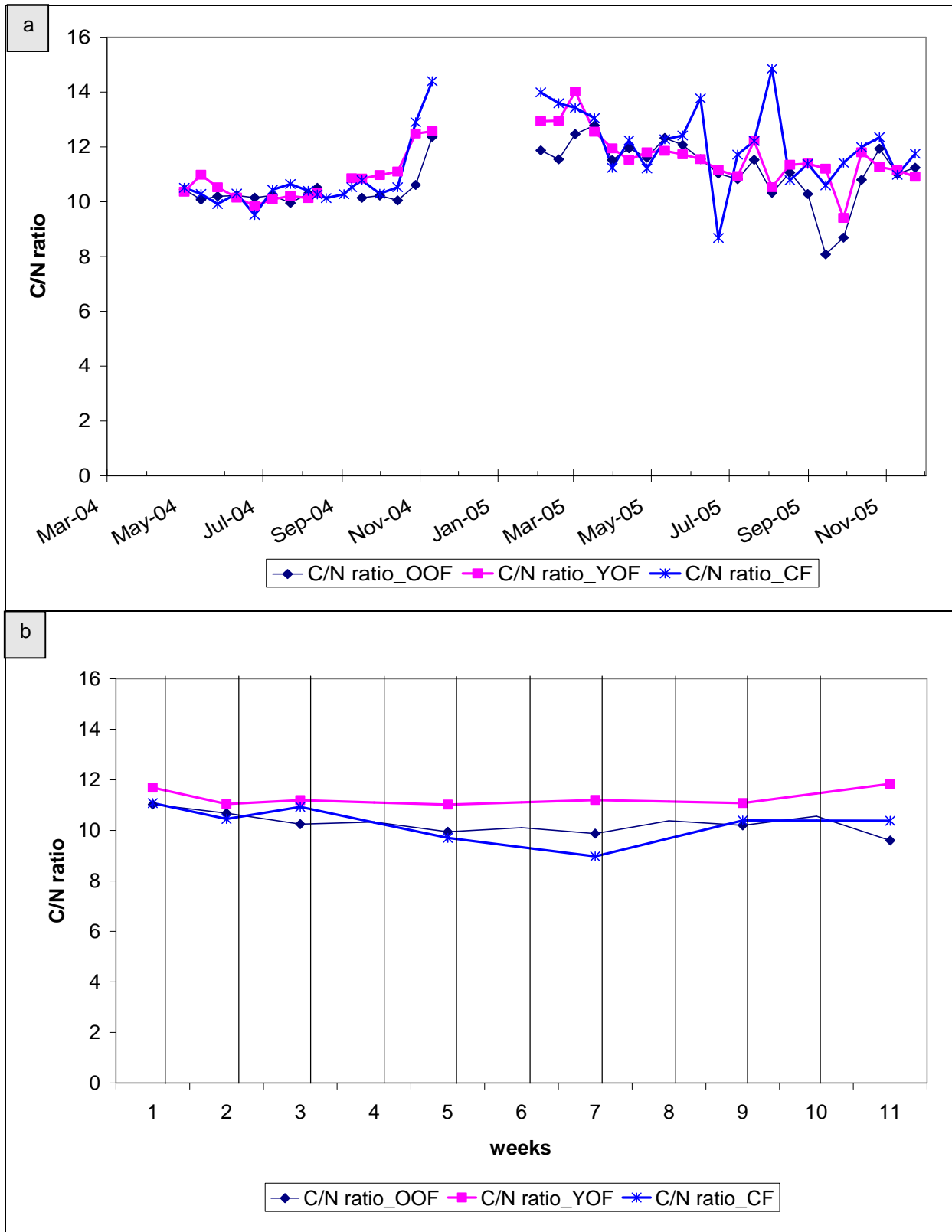


* seven day moving average

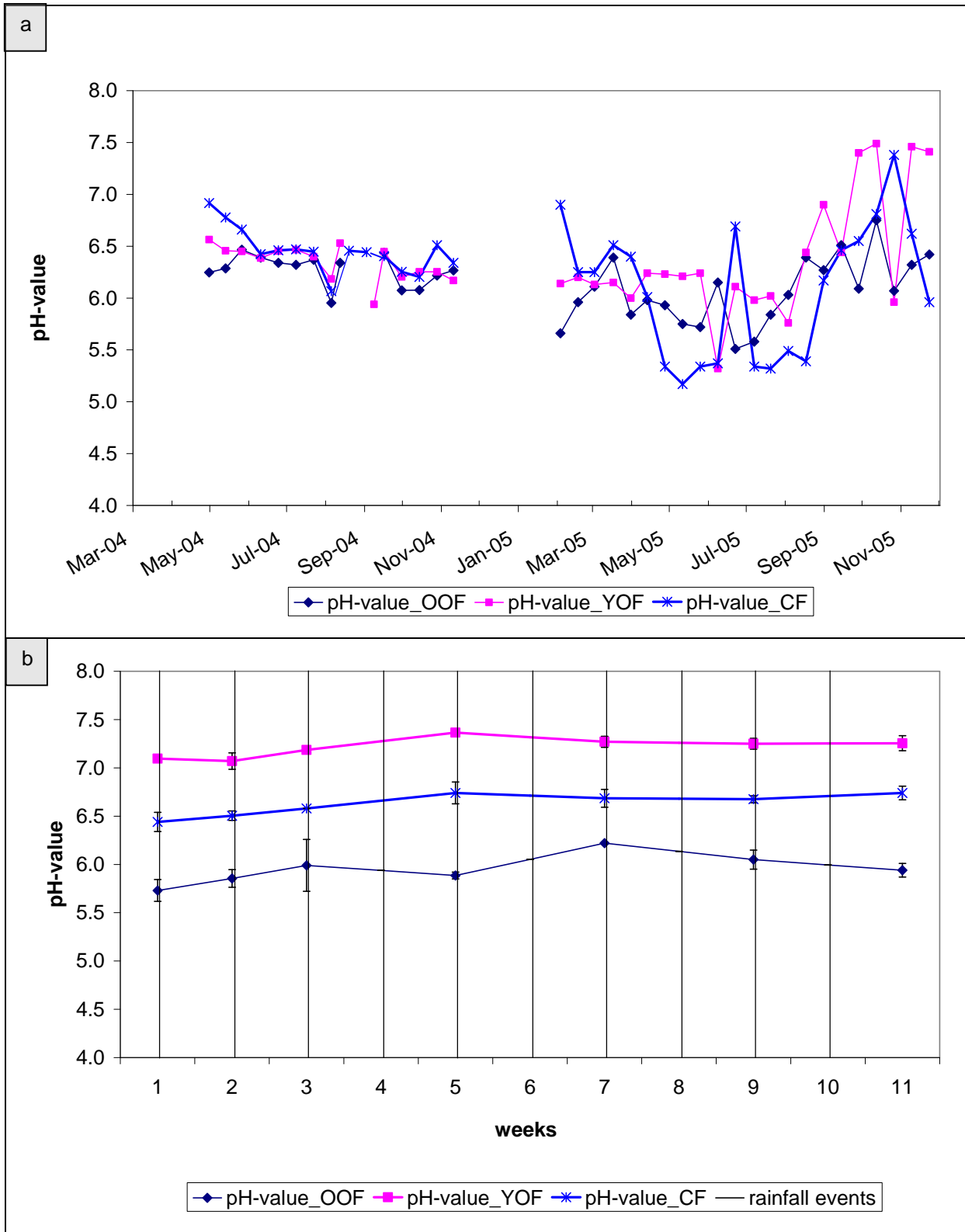
Annex 2 Soil temperature 3 cm below the soil surface during the rainfall experiment in the OOF, YOF and CF soil boxes



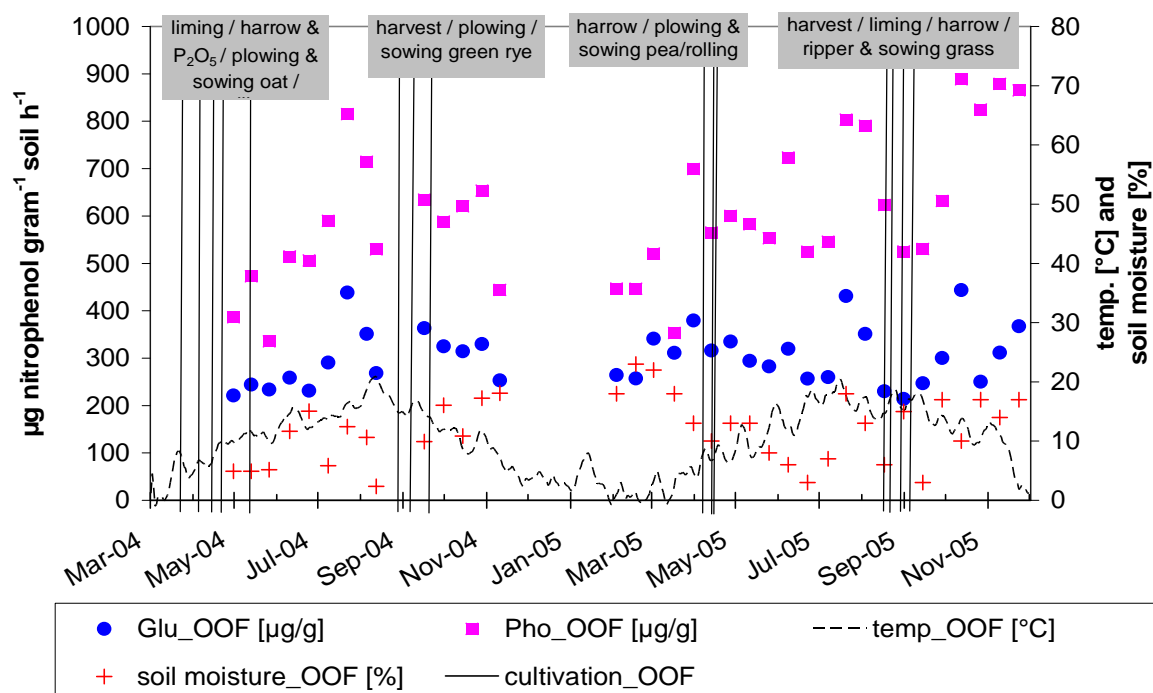
Annex 3 Nitrogen content at the OOF, YOF and CF sites in the field (a) and laboratory rainfall experiment (b)



Annex 4 C/N ratio at the OOF, YOF and CF sites in the field (a) and laboratory rainfall experiment (b)



Annex 5 pH-value at the OOF, YOF and CF sites in the field (a) and laboratory rainfall experiment (b)



* seven day moving average

Annex 6 Activity of β -glucosidase (Glu), acid-phosphatase (Pho), soil temperature (temp) and soil moisture as well as cultivation practices at the OOF site in 2004 and 2005

Annex 7 Analysis of variance (ANOVA) for aggregation ratio in 2004, 2005, 2004/2005 in the field and rainfall experiment

agg. ratio-2004	OOF	YOF	agg. ratio-2005	OOF	YOF
YOF	0.0072		YOF	0.0584	
CF	0.2009	0.0001	CF	0.0563	0.0003
agg. ratio-04/05	OOF	YOF	agg. ratio-rain	OOF	YOF
YOF	0.0010		YOF	0.8547	
CF	0.0262	0.0000	CF	0.6009	0.4819

Bold numbers indicate significant differences

Annex 8 Analysis of variance (ANOVA) for runoff in the rainfall experiment

runoff	OOF rainfall exp	YOF rainfall exp
OOF		
YOF	0.4030	
CF	0.0374	0.1752

Bold numbers indicate significant differences

Annex 9 Analysis of variance (ANOVA) for water tension 30 minutes and 60 minutes after the rainfall experiment started

water tension after 30 min.	OOF rainfall exp	YOF rainfall exp	water tension after 60 min.	OOF rainfall exp	YOF rainfall exp
YOF	0.4781		YOF	0.1189	
CF	0.0060	0.0262	CF	0.0003	0.0111

Bold numbers indicate significant differences

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Hiermit erkläre ich, dass ich die Dissertation mit dem Titel "***Assessment of dynamic biotic and abiotic processes at the soil surface affected by different management system***" selbständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt und die aus fremden Quellen direkt oder indirekt übernommenen Gedanken als solche kenntlich gemacht habe.

Die Dissertation wurde bisher keinem anderen Prüfungsamt in gleicher oder vergleichbarer Form vorgelegt.

Kiel, den 19 Februar 2007

Marcus Zeiger