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Review article

INFLUENCE OF CONVENTIONAL AND CONSERVATION TILLAGE ON C AND N MINERALIZATION IN SOIL. A REVIEW

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ABSTRACT

The mineralization of soil C and N is an important process that regulates the functioning of natural and managed ecosystems. Studies about the soil mineralizable C and N pools are essential to understand how C storage responds to changes in soil management (conservation and conventional tillage); this review was to evaluate the alterations in carbon and nitrogen mineralization due to different soil tillage systems. In this paper comes to the conclusion that conventional tillage increases net mineralization of SOM and N mineralization compared with conservation tillage.

INTRODUCTION

Tillage management in a historic context

Tillage is an essential aspect of farm management and has become a standard practice in agricultural production systems. For this review, tillage systems may be separated into two types [35], conservation tillage and conventional Tillage: Conventional tillage involving disking, chisel plowing operations aim to alleviate soil compaction and to incorporate plant residues, organic manures and weed seeds to deeper soil layers [66 and 67] and this typically entails mouldboard or disc ploughing [56]. Furthermore, tillage is used to improve soil workability [56]. In addition to tillage, is practiced for weed removal and to enhance seed germinationand seedling development by creating a suitable seedbed for root growth [16].

Conservation Tillage (CT): Any tillage and planting system that covers 30 percent or more of the soil surface with crop residue, after planting, to reduce soil erosion by water. Where wind erosion is the primary concern, any system that maintains at least 1,000 lb/acre (≈ 1.1 Mg/ha) of flat, small grain residue equivalent on the surface throughout the critical wind erosion period. The following define three broad classes of conservation tillage.

No-till or Strip-till (NT): A tillage/planting system where the soil is left undisturbed from harvest to planting except for nutrient injection. Planting is accomplished in a narrow seedbed or slot created by coulters, row cleaners, row chisels or rotor tillers. Weed control is accomplished primarily with herbicides. Less than 25% row width disturbance is considered no-till. Ridge-till (RT): A tillage/planting system where the soil is left undisturbed from harvest to planting except for nutrient injection. Planting is completed in a seedbed prepared on ridges with sweeps, disk openers, coulters, or row cleaners. Residue is left on the surface between ridges. Weed control is accomplished with herbicides and when ridges are rebuilt during cultivation.

Mulch-till (MT): The soil surface is disturbed prior to planting. Tillage tools such as chisels, field cultivators, disks, sweeps or blades are used. Weed control is generally accomplished with herbicides and/or cultivation.

Reduced Till (RDT): Any tillage system that leaves 15–30 percent residue cover after planting, or less than 500 lb/acre (≈0.55 Mg/ha) of small grain residue equivalent throughout the critical wind erosion period.

Conventional tillage (CT) is perceived to be less sustainable compared to conservation tillage (CST) since it greatly perturbs the soil. This is caused by the use of (mouldboard) ploughing, which results in soil inversion to a depth of approximately 25-30 cm, with the soil surface remaining bare and unprotected (Table 1). Nowadays, one of the biggest problems of agriculture associated with CT is increased sensitivity to erosion and compaction [14], which is threatening 157 million hectares in Europe [27].

Modern conventional tillage includes a large number of serial passages in the preparation of soil for planting. After planting the soil surface remain uncovered until development of the crop and as such exposed to precipitation and wind. The result of such a situation is erosion, damage to soil structure and nutrient losses (run-off and leaching to deeper layers) [70]. In such conditions, soil cultivation additionally speeds up the decomposition; the more intense, the faster is the decomposition of organic matter. Deep intensive tillage incorporates plant residues into the soil, and also physically damages soil aggregates and exposes humus which was before protected in the structural aggregates, which facilitates decomposition of soil organic matter by soil organisms [74].

An integral part of conservation agriculture (CA) often is CST [67] and becomes increasingly important in farm and soil management at different levels [14] (Table 1). A requirement for CST is that soil coverage by plant residues is at least 30% [17] (Table 1) and that non-inversion tillage (NIT) is being practiced. Soil degradation, erosion and water contamination are expected to be greatly reduced through use of NIT techniques [32].

Table 1: Different tillage practices and related soil operations [67].

Conventional tillage(ct)		**Soil operation**: (m0ldboard) plowing **Result**: soil invertion (±25cm) prior to planting. Litter or no plant residues remain on the soil surface
Conservation tillage(CsT):	Reduced tillage (RT)	**Soil operation**: A range of superficial, mechanical soil loosening operations (disks, chisels, sweeps, etc) **Result**: loosing of top soil (5-10 cm), leaving a large (30) amount of plant material on the soil surface **Synonym**: minimal tillage **Specific variants**: mulch tillage, ridge tillage, strip tillage
	No tillage (NT)	**Soil operation**: no soil operations prior to planting, seeds are put in narrow grooves cut into the soil **Result**: virtual all crop residues are left on the soil surface **Synonyms**: direct drill, Zero tillage (ZT)

In CST both reduced tillage (RT) and no tillage (NT) practices may be used [32 and 67]. With RT or “minimum tillage” (MT) techniques a superficial loosening of the topsoil (0-10 cm) is used, while NT does not include any soil operations at all. Synonyms of NT, direct drill (DD) and zero tillage (ZT), are also commonly used (Table 1). Crop requirements and inherent soil structure determine the success of DD, which is not suitable for root crops [16]. Above mentioned terms of the various tillage-types are often incorrectly used in literature.

Key advantages of conservation tillage

Most advantages of CST are indirect in terms of enhancing production potential (e.g. soil quality) and/or only become more articulated after several years, while the conversion to CST requires additional investments in terms of learning, management and/or equipment. However, a direct advantage may be the reduction in fuel consumption, because conventional tillage is not practiced anymore. Moreover, lower energy and labour requirements [33]. Combined with reduced maintenance of machines may result in an appreciable reduction in overall energy use [11 and 67]. Furthermore, CST tends to be more environmental friendly since soil erosion is being reduced, due to improved aggregate stability and common use of cover crops [62]. Another advantage is that runoff-induced loading rates of nutrients, sediments and pesticides to surface water decreases between 15% and 89% [3and 32], thereby improving surface water quality [52, 67 and 69]. Moreover, risks for sealing and/or crusting are being reducedand the carrying capacity and soil accessibility under wet conditions is increased by an improved drainage (by earthworms) and water retention [62, 38 and 56]. Finally, NIT also increases carbon sequestration, although benefits are mainly reported for the topsoil [10, 11,30, 48 and 63]. According to Baker et al. [4] a review of multi-year experiments, with tillage as variable, showed a positive effect of carbon sequestration with NIT being practiced.

Disadvantages of conservation tillage

Despite its potential benefits in terms of reduced energy use and soil conservation, NIT also has some (initial) disadvantages. Subsoil dry bulk-density and soil-aeration respectively are reduced [63]. Moreover, a decline in N mineralization and related N-supply may reduce crop N uptake, especially during the initial five years of practicing NIT [48 and 66].

According to Koepke [36] soil tillage may be required to increase N-availability by improving microbial activity, rooting-density and nutrient absorption. However, lower N-application may be sufficient once new soil equilibrium has been reached and occurs around 20 years after the last inversion-tillage [67]. Next to lower aeration and N-supply it was reported by Van der Weide et al. [67] that hydraulic conductivity (Ks) decreases and penetration resistance (PR) increases in DD systems. Moreover, seedbed preparation was hindered due to plant residues being left on the topsoil, which hampers the use of standard planters [28]. Another problem arises in organic farming systems, in which weeds tends to become a more severe problem, with a higher weed coverage [11], more persistent grass weeds [48] and a higher weed diversity with NIT being practiced [73].

The role of carbon and nitrogen in soil

Soil organic C (SOC) and total N (TN) contents play a crucial role in sustaining soil quality, crop production, and environmental quality [9, 21 and 53] due to their effects on soil physical, chemical, and biological properties, such as soil water retention, nutrient cycling, gas flux, and plant root growth [54 and 55]. Soil, as an open system, can be a net source of CO2 released to the atmosphere due to elevated SOC mineralization as a result of disruptive agricultural practices. On the other hand, soil can function as a net sink for sequestering atmospheric CO2 under appropriate soil and crop management, and thus reducing atmospheric CO2 [41, 46 and 47]. Plant biomass is a source of C and N, which can replenish SOC and TN. Changes in soil conditions (e.g., temperature, moisture, O2, pH, and nutrient availability), can alter the decomposition rate of plant biomass and the mineralization rate of soil organic matter [14, 18 and 37]. Therefore, SOC and TN can be enriched via appropriate soil and management practices (specific tillage) that either increase organic matter input to the soil, decrease the mineralization rate of soil organic matter, or both [22, 46 and 47].

Difference between of conventional and conservation tillage on C and N Mineralization in soil

One of the main agronomical challenges is achieving or maintaining a high level of soil organic matter, while keeping the concentration of inorganic nitrogen low during periods subject to leaching losses.

The major components of C, N transformations and transfers in soil organic matter are requisite to accurate accounting of nutrient budgets under selected tillage and amendment management practices. Carbon and N stabilization or mobilization processes in soils are considered to be coupled and are mediated through microbial energy requirements [29].

Microorganisms are the active component of soil organic matter. They rapidly respond to the changes in the soil temperature, moisture content, crop residues [52]. Due to the quick response of microorganisms to the soil conditions, microbial biomass-C content could also be a good indicator of soil tillage induced changes [1]. The release of available N for crop uptake depends on the mineralization immobilization balance in organic matter turnover. The amount and timing of mineralization is favored by several factors including soil moisture, aeration and temperature, and by the nature and accessibility of organic materials to the microbial biomass [12]. Fresh organic matter input with a high labile SOM fraction improves the mineralization rate by increasing microbial activity. Soil microbiota is responsible for nutrient mineralization through organic matter decomposition. Microbial biomass represents only 5% of soil organic matter, but it is an important reservoir of soil nutrients because many transformations of these nutrients occur in the microbial biomass [20]. Therefore, soil management (tillage and groundcover species cultivation) has great effects on a soil's chemical, physical and biological properties and on plant's growth and nutrition patterns.

It has been suggested that when residue is left on the soil surface, the nitrification can be inhibited due to the presence of the organic matter. Additionally, N may accumulate at or near the soil surface and restrict N-mineralization [13].

Mineralization of N from soil organic matter can provide a useful integration of chemical, physical and biological aspects of soil health because it combines the accumulation of N through previous biological activity, the present organic matter status of the soil and the current N mineralization activity of soil microorganisms [61]. Many studies showed that there were higher amounts of soil organic matter, enzymes and microbial biomass in the soils under conservation tillage in comparison with those under conventional tillage [19, 43 and 50]. Compared to conventional tillage, various kinds of conservation tillage proved to markedly affect soil fertility and organic matter dynamics [44]. Decreasing tillage intensity from the conventional tillage (CT) to zero tillage (ZT) generally leads to crop residues remaining on or near the soil surface, resulting in a stratification of organic matter and nutrients within the plough layer compared to an even distribution in CT [63 and 64].

Tillage plays an important role in the manipulation of nutrient storage and release from SOM, with conventional tillage (CT) inducing rapid mineralization of SOM and potential loss of C and N from the soil. A global analysis of 67 long-term experiments indicated that on average a change from CT to no-till (NT) can sequester 57 ± 14 g C m^{-2} $year^{-1}$ (excluding NT in wheat fallow systems) with peak sequestration rates being reached within 5–10 years after conversion [71]. By contrast, Six et al. [57 and 58] found a general increase in soil C contents of 325 ± 113 kg C ha^{-1} $year^{-1}$ under NT compared with CT for both tropical and temperate systems. They also reported that, on average C turnover was 1.5 times slower in NT compared with CT.

Mineralization of the SOM is affected by the tillage system; Conventional tillage disrupts aggregates, exposes the SOM, and increases its decay rate. This phenomenon is due to an increase in the aeration and the temperature of the tilled layer, to the incorporation and mixing of C inputs improving microbial activity, and the release of previously physically protected SOM [5]. The timing and intensity of conventional tillage events affect net mineralization. For instance, more N is released when tillage coincides with periods of high soil temperature and/or moderate soil moisture [49]. Compared with conventional tillage, conservation tillage creates more compact and cooler soil. The result is slower mineralization and the release of plant nutrients from soil organic matter [21].

Soil organic C under conservation tillage was numerically greater than conventional tillage in all studies for near-surface depths,

Thus, conventional tillage increases net mineralization of SOM compared with conservation tillage. In conservation tillage, especially no tillage, there is a greater pool of soil labile N from microbial activity in the surface layer. However, this pool has a slower turnover rate caused by the decrease of the decay rate of SOM [5 and 66]. Pekrun et al. [49] indicated that net N immobilization can occur with slow SOM turnover during the transition period from conventional to conservation tillage. Moreover, soil compaction also affects the mineralization of soil C and N [31].

Thus, topsoil compaction in conservation tillage alters the habitat of soil micro organisms and consequently their activity by modifying the content and diffusion of soil gases (CO2 and O2) and soil water [6]. For instance, more denitrification can occur [7], making less N available for crops. As many of the benefits of conservation or no tillage depend on enhanced microbial activity, [5] suggested that these techniques were best suited, for general use, in semi-humid or drier regions. Due to these effects of conservation tillage on SOM turnover, although soils managed by conservation tillage contain similar overall amounts of mineralizable N to conventionally tilled soils, in the short term less mineralized N is found than in ploughed soils.

Koepke [36] and Vakali et al. [65] found less mineralized nitrogen in shallow tillage than with ploughing. Although SOM content can increase in farmlands, the lack of mineral N input may slow down the supply of available N to crops. As conservation tillage increase earthworm numbers, their activity in physically breaking down organic residues thereby encouraging microbial activity could lead to improved N release.

N mineralization was higher in the plowed soils in soil depths. N mineralization started faster in the plowed soils, especially in the upper layer of soil. This could be explained by more plant residue concentrated in the upper layer at N treatment. Plant residue (fresh and from previous years) can cause temporary immobilization of N released from soil by mineralization. Immobilization is significant if the C/N ratio of plant residue is >20 – 25 [45]. Soon and Clayton [60] suggested that this would have a positive effect on decomposition processes of crop residues by microbes. In another study, they observed that microbial biomass carbon turnover was higher with no-till than conventional tillage but slower. Nitrogen mineralization has also been reported to be higher with no-till but slower. For this reasons, in without tillage mineralization of nitrogen during fallow was reduced which could affect fertilizer needs. The latter agrees with many studies that have evaluated the effect of tillage on N cycling and have concluded that higher N mineralization is associated with no-tillage compared to standard tillage; many studies have shown that differences in biochemical characteristics of soil amendments can lead to differences in N mineralization [33, 39 and 68]. Compared to conventional tillage, conservation tillage under organic management enhances SOC concentration, soil microbial biomass, enzyme activity, select plant nutrients, N mineralization potential, and earthworm abundance. Conversely, conservation tillage effects on soil structural attributes and pH are mixed or unchanged compared to conventional tillage. Long-term use of conservation tillage can contribute to near-surface accumulation of plant nutrients and greater nutrient mineralization potential in non-organic production systems [72]. Inversion tillage results in increased CO2 emission, with emission levels gradually declining with time [52]. Compiled results across six studies underscored potential benefits from tillage reductions for conserving SOC in organic production systems. Soil organic C under conservation tillage was numerically greater than conventional tillage in all studies for near-surface depths, with absolute and relative differences between treatments averaging 1.1 g C kg^{-1} and 6%, respectively.

Differences in SOC between conservation and conventional tillage for surface depths ranged from 0.2 to 4.5 g C kg^{-1}, and were strongly associated with treatment duration ($r = 0.98$; $P \leq 0.01$), which varied from one to six years. Soil organic C was greater under conservation than conventional tillage below 10 cm for two studies (Range = 0.3 to 0.9 g C kg^{-1}) [26 and 69]. Though reported studies concentrated on SOC, Lewis et al, 2011found labile C 14% greater under conservation than conventional tillage during the third year of a transition to organic management.

Conservation management resulted in a significant increase in soil organic C at the soil surface. Accumulation of soil organic C at the soil surface was a result of surface placement of crop residues and a lack of soil disturbance that kept residues isolated from the rest of the soil profile.

Soil organic C under CT compared with NT at a depth of 7.5–15 cm in Georgia was a result of tillage operations that incorporated surface organic C throughout the 15 cm tilled zone. Decomposition of surface-placed residues is often slower than when incorporated in the soil profile [15 and 29], primarily because of less optimal moisture conditions (Franzluebbers et al., 1996). Due to the less than optimal decomposition environment when soil is left undisturbed and residues are at the surface compared with disturbance and incorporation with tillage, transformation of organic C from plant-derived residues into soil organic C may be more effective under NT than under CT [23, 24 and 25].

CONCLUSIONS

Finally, soil organic carbon (SOC) and nitrogen contents in conservation tillage system are more than conventional tillage, however conventional tillage increased C and N mineralization rate compared to conservation tillage. Also mineralization of organic matter in conservation tillage is slower than conventional tillage. In the other hand, aggregate formation under conventional tillage by the flush of microbial activity after the disruption of aggregates or incorporation of residue may be increased. Net mineralization of soil organic matter (SOM) which is the main source of nitrogen in conservation tillage is reduced.

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