VAN HALL LARENSTEIN

Non-inversion system promotes soil physical factors and earthworm community

- Possible transition from conventional tillage system to non-inversion tillage system

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Abstract:

Since the long term consequences of standard tillage be noticed, there are increase number of attention be put on non-inversion tillage, and no- tillage systems, which can increase the density and diversity of earthworm while bringing positive effect of infiltration, retention, and soil aggregates stability to improve the quality of farming land (Schjønning and Rasmussen, 1989], [Schjønning, 1992], [Rasmussen et al., 1995] and [Djurhuus and Olesen, 2000]). However, no-tillage systems may not be appropriate in humid-temperate climates due to excessive moisture content in spring, resulting in reduced traffic ability and seedling emergence (Poot et al, 2012). Non-inversion tillage system is also tillage but without inverts the soil. Conventional tillage system in EU region is cultivated by using plough, which process intensively inverts the agricultural field. Implement with heavy machinery (tracks), standard tillage (ST) system will change the soil structure and organic matter content and further influence negatively on agricultural fields. Comparing with ST, NIT have better water infiltration and retention, which the soil can infiltrate extra water in rainfall and hold more water when drought.

Our research would focus on the soil quality (water infiltration and retention, bulk density, earthworm and soil aggregates stability) in different treatments both France and Netherlands. Sand box and suction plate would be used to measure the water retention, and the Double ring method will also applied for water infiltration. The penetration resistance measurement will be done by using Penetrometer and the result will come from two depths: 0-10cm and 10-20cm, we also will use wet sieving method according Elliot (1986) to measure the aggregate stability. After that we would compare the overall data, and explain the difference of soil quality and earthworm density in two different treatments to find out the reason NIT is more suitable than ST in farm land.

1.Introduction:

Climate change is still the hottest topic for now. As we know, because of the greenhouse effect, the average surface temperature is increase more than 1 degree Fahrenheit since 1900(IPPC,2007), which also lead to the ice mountain melt, sea level raise, and soil erosion. The Triplett` study (No-tillage and surface-tillage agriculture,1986) shows that there are more than 40% land in the world are farming land , improve the soil quality and soil structure by applying different tillage treatment can significant decrease the soil erosion.

Conventional tillage system in EU region is cultivated by using plough, which process intensively inverts the agricultural field. Implement with heavy machinery (tracks), standard tillage (ST) system will change the soil structure and organic matter content and further influence negatively on agricultural fields. In other words, those soils are trend to erosion and run-off, and the soil quality also would be decrease. Such potential risk will decrease the value of agricultural lands or even lead to desertification (Biswas, 1994).

Comparing to this conventional tillage system, the no-tillage system have no activities to influence the soil structure which means NT (no-tillage) soil would contain high quantity of organic matters and organisms (Govaerts et al, 2005). But the fact is NT agriculture lands rare exist in Europe, but the success of NT depends on site specific factors (e.g. soil type), weather conditions and the number of years since implementation of the tillage system (Rhoton, 2000). In Europe’s Mediterranean areas, NT may reduce erosion and improve water holding capacity (Cantero-Martínez et al., 2007). However, in Northern Europe, excessive moisture content and slow temperature rise during spring may reduce traffic ability, seedling emergence and crop yield (Licht and Al-Kaisi, 2005; Soane and Ball, 1998). Furthermore, crop rotations often include tuber crops that, due to the use of heavy machinery and preparation of ridges for certain crops cause a lot of soil disturbance. Therefore, NT may not be an appropriate system in temperate climate with high rainfall (Lampurlanés et al., 2001) or in crop rotations including tuber crops (D'Haene et al., 2008).

An intermediate between ST and NT is non-inversion tillage (NIT). This system so in our case, we would focuses on the intermediate system between ST and NT, which is non-inversion tillage.

The long-term side effects of ST system switches research interest in alternative tillage system. Non-inversion tillage (NIT) system as a type of conservation tillage system will be introduced. The NIT system allows farmer to break up the compacted layer without inverting the soil. Different from ST system, at least 30 per cent residue cover of agricultural site will be retained under NIT treatment and the seedbed will not be totally inversed (Easterling et al 2000). The NIT treatment considered mostly keeps the soil structure and may lead to benefit soil organic matters further promoting the soil resilience to extreme weather conditions.

As the soil ecosystem engineer, earthworms are also very important part of soil physics, they are among the important soil invertebrates that influences crop production and contribute to soil ecosystem services through (Ulrich et al., 2010) by increase the macro pores and earthworms can bring large amounts (ranging from 2 to 250 tons /ha-1/year-1) of soil from deeper layers to the surface. In temperate climates the upper 15 cm of the soil profile may be turned over in 10 to 20 years (Edwards et al., 1996). Earthworms improve the soil physical properties like soil structure, aeration, infiltration, soil aggregation, and contribute to soil organic matter dynamics and nutrient availability (Lee, 1985) On one hand, the cast formed by earthworm activity can increase the C storage which contribute to the C sequestration and also reduce the CO_2 in the atmosphere(Shipitalo et al., 2004)), on the other hands, the earthworm activities in soil can produce more macrospores which can lead to higher infiltration capacity and water conductivity, meanwhile, losing soil to provide a better growth condition for crops.

The bachelor thesis had mainly studied on the water infiltration and retention, bulk density and soil aggregates stability and samples were taken from experimental sites: Brittany (France) and Lelystad (Netherlands). The perspective of comparable experimental sites was from prospecting similarity (soil physical quality) between two experimental sites under similar treatments. The time schedule of research was attached in appendix 2.

2. Objective and hypotheses:

The overall thesis objective was evaluating soil physical quality and earthworm density and diversity related to tillage treatment. In addition, the research was conducted in Netherlands and French experimental sites.

We hypothesized that NIT system compare with ST system, will:

a. Improve the earthworm density in the field.
b. Change the soil physical factors through decreasing the soil infiltration capacity, increasing soil aggregates stability, water retention capacity and penetration resistant.

3. Materials and Methods:

3.1 Experimental sites:

The research had been conducted in Netherlands (PPO Lelystad) and French (Kerguéhennec) sites. As experimental sites, different treatments were implemented and represented different type of soil management (tillage treatment and fertilizer).

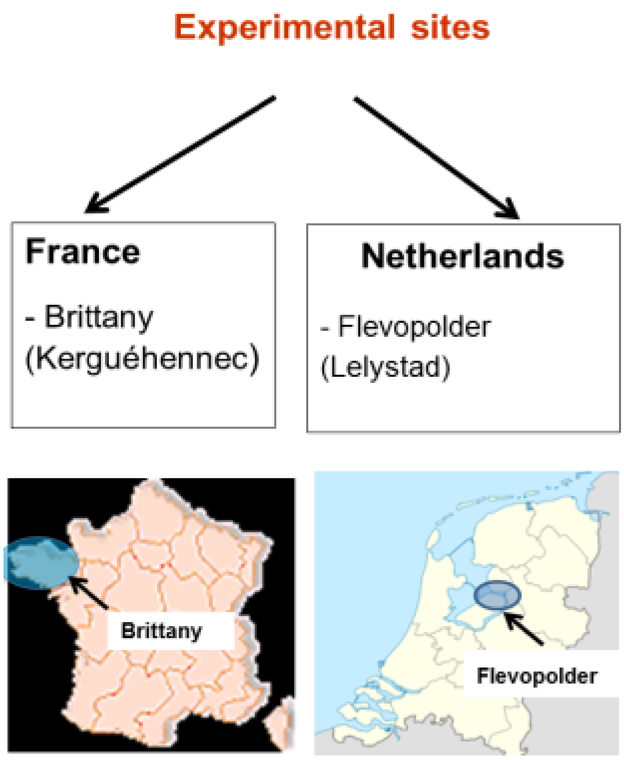

Figure 1. The location of experimental sites: Kerguéhennec and Lelystad

Experimental site: Kerguéhennec

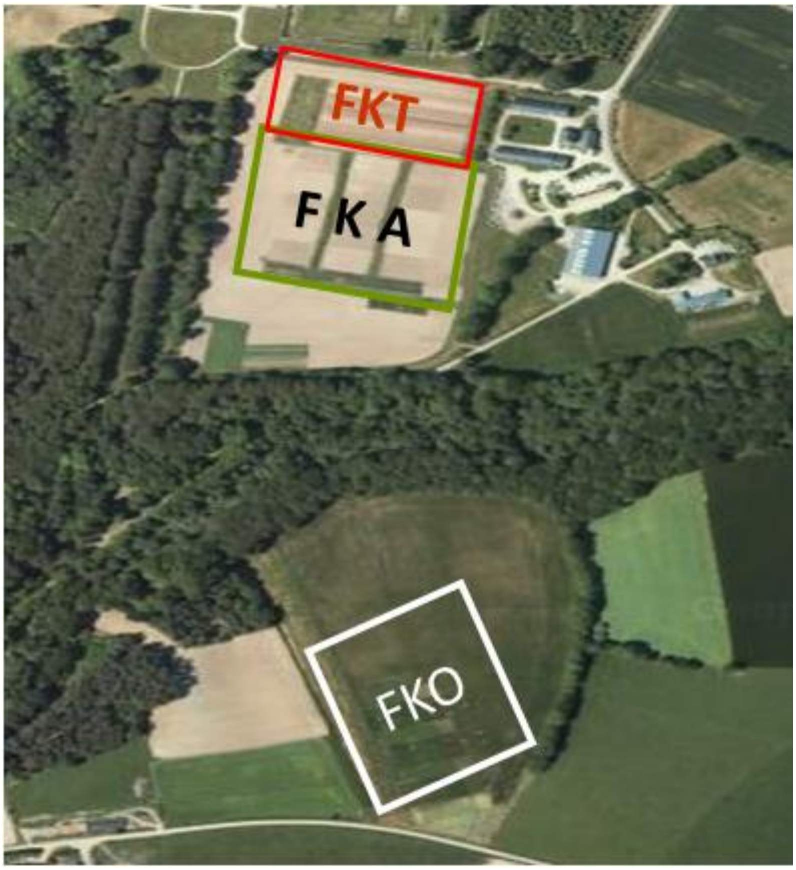

Figure 2-1. Layout of experimental site: Kerguéhennec

The abroad experimental site Kerguéhennec (see Figure 2-1) locates in the northwest of France. This experimental field had been implemented since 2000s and there were two experimental designs under conventional system (FKT and FKA) and one experimental design under organic farming (FKO): (1). FKT is the field under "transfer" experiment testing on run-off impact. (2). FKA is the field with "agronomic" experimental testing on organic matter inputs and tillage. (3). FKO is the "Organic" experiment field (see appendix 3 and 4). The temperature and annual precipitation of experimental site are 10.9℃ and 637mm (FAO: Climate tool, 2012). FKA and FKO were our thesis research fields.

Experimental site: Lelystad

Figure2-2. Layout of experimental site: Lelystad

PPO lelystad was the experimental site (see Figure 2-2) in Netherlands, where two different tillage systems (NIT and ST) were compared under organic and conventional farming. The treatments had been implemented since autumn in 2008. The weather condition of Lelystad is with an average annual temperature is 9.7 ℃ and the average annual precipitation 825 mm (Sluijter, 2011). Across the whole experiment, irrespective of tillage treatments, controlled traffic is used with in which all wheel traffic, except for harvest and ploughing, is confined to permanent tracks of 3.15m spacing using a RTK-GPS operated tractor (Natajsa, 2012).

The experiment fields were J9-2b and J10-3 (see Figure 2-2). The treatment type of J9-2b was integrated treatment and the plant rotation was winter wheat, onion and potation from 2010 to 2012. The crop planted in J9-2b was sugar beet in 2012. Field J10-3 was cultivated under the organic treatment. The crop rotation was Grass clover, white cabbage and summer wheat. And the crop planted this year was summer wheat in 2012.

3.2 Treatment description:

Kerguéhennec

There were three blocks in field FKA and each block were cultivated under six same treatments which was identified by plough intensity and manures (see appendix 3):

1. Ploughing intensity: plouging (P), reduced tillage (RS) and no till (NT)
2. Manures: poultry manure (PM) and mineral (M)

Field FKO had three blocks and each block had four same treatments distinguished from plough intensity (See appendix 4). The treatments were:

1. Conventional tillage (CT): standard ploughing with a mouldboard plough to a depth of 20cm.
2. Agronomic ploughing (AP): agronomic ploughing with a mouldboard plough to a depth of 15cm.
3. Reduced tillage (R15 & R8): non-inversion system harrowing to 8cm and 15cm respectively.

Lelystad：

The experimental sites were laid out in randomized block. The treatments were as follows:

1. Standard ploughing (ST) during autumn with a mouldboard plough to a depth of 25 cm
2. Non-inversion tillage (NIT) with a subsoil to 20 cm depth and partial residue retention

In this system, a six-year crop rotation is used including carrots and potatoes. No artificial fertilizer or chemical protection was applied (Natasja, 2012). The crop grown in 2012 was potatoes.

3.3 Field measurements:

Water Infiltration:

The sample instrument of water infiltration was double ring infiltrometer. During the preparation, the samples instrument would be partially inserted into soil and filled with water. The residues on surface were removed from measurement site ensuring the instrument could be really inserted in case of leakage. Soil surface protection was mainly conducted by spreading water through sponges placed in double rings. Besides, the top of double ring should be horizontal and equal altitude reducing the reading error. During the measurement, water level in outer ring and inner ring had been keeping same to avoid pressure height differences. The water infiltration speed (cm/min) was recorded as result. In addition, the advantage of double ring measurement was the outer ring limiting the lateral spread of water after infiltration (eijkelkamp, 1999), which promoted the veracity of measurement.

Figure 3-2. Water Infiltration measurement

Infiltration capacity can be altered by soil management practices (VitiNotes, 2006). As water infiltration capacity was related with soil structure, any practice effects on the structure of soil would shift the water infiltration. Therefore, water infiltration could be a good indicator for monitoring soil structure.

Water Retention curve:

Soil water retention is a major soil hydraulic property that governs soil functioning in ecosystems and greatly affects soil management (W.J. Rawls, Y.A. Pachepsky, J.C. Ritchie, T.M. Sobechi, H. Bloodworth, 2003).

During the sample collecting, intact soil cores of 100 cm^3 were collected at depths of 0-10 cm and 10-20 cm and three samples were taken from each plot (Nataja, 2011). Soil water retention capacity was measured using a combination of the sand box and suction plate at different pressure value. The water retention capacity had been measured at PF 0, 1, 1.3, 1.69, 2, 2.19, 2.49, 2.79, 3.20, and 4.19. The measurements under the pF 2 were conducted in sandbox and the further the measurements were finished in suction plate and pressure plate. Measuring period increased with pF value due to the pore size (water retention capacity will grow oppositely with the pore size and the water held in macro-pores will be first sucked).

Figure 3-2. Suction plate and sand box.

Earthworm density measurement:

During the field work, 3 samples were taken per plot, on each of the 4 plots per treatment per field. One cube soil of volume 20cm x20cmx20cm would be taken out from the ground. And earthworm in the cube of soil had been collected by hand sorting. Besides, 0.5 L formalin would be poured into the hole. This process was aiming to see if there would be anecic (the earthworm species build permanent burrows into the deep mineral layers of the soil) (Colorado State university, 2011) coming out, which would be also taken in to analysis. The abundance and weight of

EW measurement would be converted to earthworm density in 1 m^2.

The earthworm abundance and weight had been accounted in the lab. Afterwards, the earthworms would be kept into alcohol with 98% concentration for further species identification. However, the earthworm identification is still processing, which will be not included in the thesis research.

Soil aggregates stability:

The soil aggregates stability measurement analysis was based on the comparison from different tillage systems and depth (0-10cm and 10-20cm).

During the field work, 3 samples were taken per plot, on each of the 4 plots per treatment per field. The samples would be sieved by 12mm and to be air-dry by 48 hours afterwards. The processing was the preparation for measurement.

Start with samples preparation, the samples from same block and depth had been randomized first and kept only 50 grams for further measurement. The kept samples would be sieved in distilled water with 2000μm, 250μm and 53μm meshes (started from 2000μm to 53μm0. Each sieving process would take 2mins and 50 times. The soil from different classes after sieving had been placed into oven for 24 hours with 60℃. Besides, in the beginning of sieving (in mesh 2000μm), the soil had been left for 5 minus to natural break the soil particles.

Penetration resistance:

Soil penetration resistance was measured with penetrometer, data were took from field J10-3 (maps attached in appendix 7) to 80cm depth, with two treatments: NIT and ST. Data were measured in 8 plots, 10times for 1 plot, so in total we have 1600 data for those two treatments. After that, we analyses the data with averaging the value of 10 samples from the same depth and plot, categorizing them in two treatments.

Figure 3-3. Soil penetrometer

The penetrologger is a versatile instrument for in situ measurement of the resistance to penetration of the soil. The cone is screwed on the probing rod, which is connected with a quick coupling to the force sensor on the penetrologger. Now the cone is pushed slowly and regularly into the soil. The depth reference plate, which is on the soil surface, reflects the signals of the ultrasonic sensor, which results in a very accurate depth measurement. The depth reference plate is also used to reflect the signals which are used to control the penetration speed. The measured resistance to penetration and the GPS coordinates are stored in the internal logger of the penetrologger. Depending on the application and the expected resistance to penetration, various cones can be connected to the probing rods. Optional is the possibility of soil moisture measurement with an external soil moisture sensor (Eijkelkamp)

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4. Result and discussion:

4.1 Field measurement:

Kerguéhennec

In field FKA, comparing with fertilizer, the tillage treatment did not strongly influence on water infiltration.

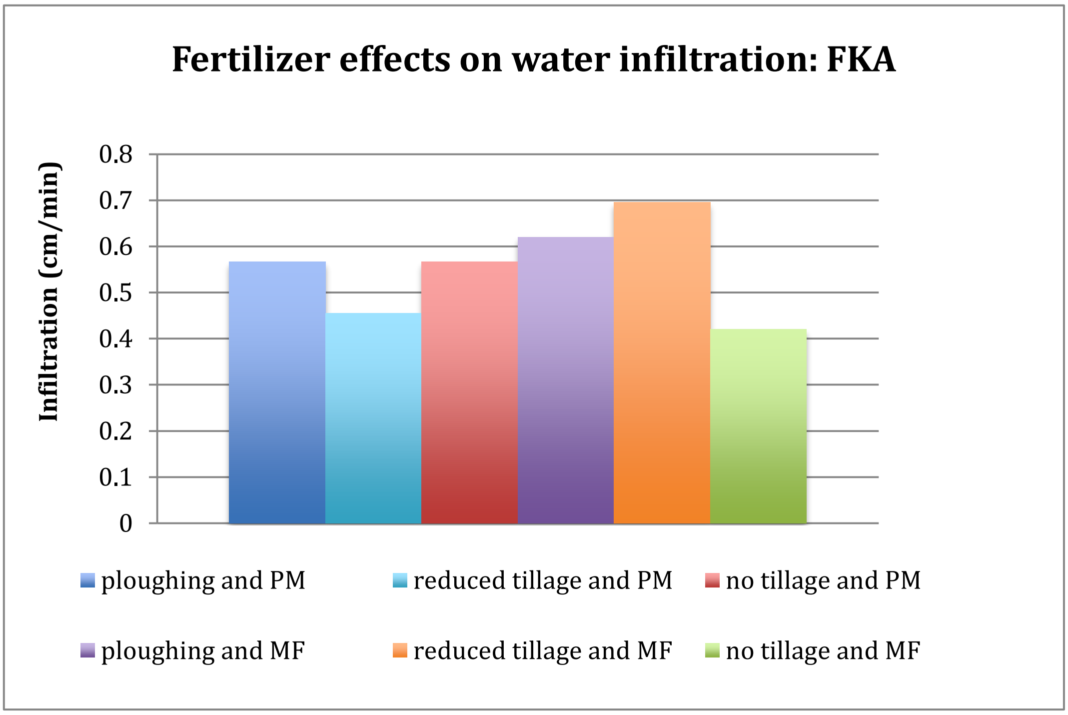

Figure 4-1. The water infiltration capacity in field FKA under different tillage system (ploughing, reduced tillage and no tillage) and fertilizers (poultry manure and mineral fertilizer)

Under the poultry manure (PM), the water infiltration of ploughing treatment and no tillage treatment were 0.57 cm/min and 0.57 cm/min respectively. The water infiltration of reduced tillage treatment had lowest capacity, at 0.46 cm/min. Under the mineral fertilizer (MF), the water infiltration of reduced tillage system was 0.7 cm/min and was the highest one. The water infiltration of no tillage treatment was only 0.42 cm/min and the water infiltration of plough was 0.62 cm/min. According the analysis on water infiltration capacity considering fertilizer aspect, the fertilizer type did not seem to have an effect, on average, and so was removed from the analysis.

To be more specifically on the influence of tillage treatment on water infiltration, the Figure 4-2 only demonstrates the average water infiltration of three tillage treatments, ignoring the different fertilizer.

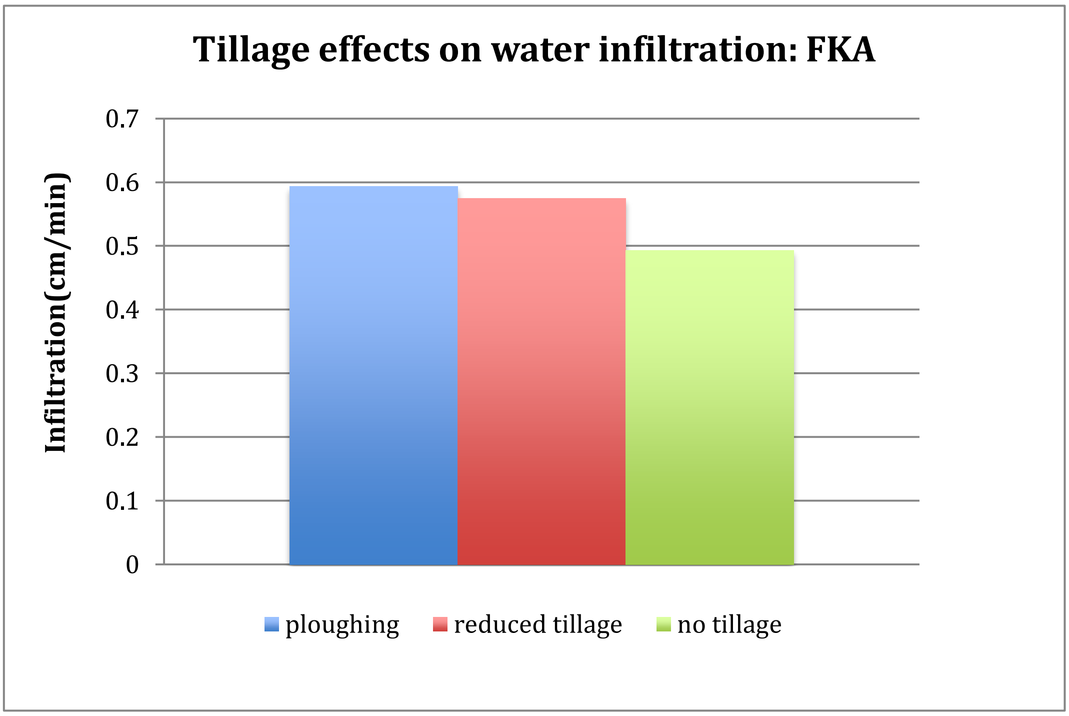

Figure 4-2. Water infiltration comparison under different tillage treatment (ploughing, reduced tillage and no tillage)

According to the Figure 4-2, the water infiltration capacity was decreasing with the tillage intensity. The water infiltration speed of ploughing treatment was the highest and reached 0.59 cm/min. The water infiltration capacity of reduced tillage treatment was 0.58 cm/min. And the lowest water infiltration is the no tillage treatment, which had only gained 0.49 cm/min.

According the bar chart below (field FKA), the water infiltration capacity of treatment C15 and C8 were similar, staying at 0.34 cm/min and 0.34 cm/min respectively. And the water infiltration capacity of C15 and C8's were lower than water infiltration speed of CP and AP treatment. Relatively lower water infiltration capacity of chisel treatment could be explained from different tillage treatment. Comparing with the ploughing treatment, the chisel treatment had protected the soil structure and decreased water infiltration capacity. However, the water infiltration capacity of chisel treatment did not strongly influenced by chiseling depth. The water infiltration speed of conventional ploughing treatment was the fastest, reached at 0.57 cm/min. And the water infiltration of agronomic ploughing treatment was 0.42 cm/min. In conclusion, the water infiltration capacity was increasing with tillage intensity positively, which was similar with the result from field FKA.

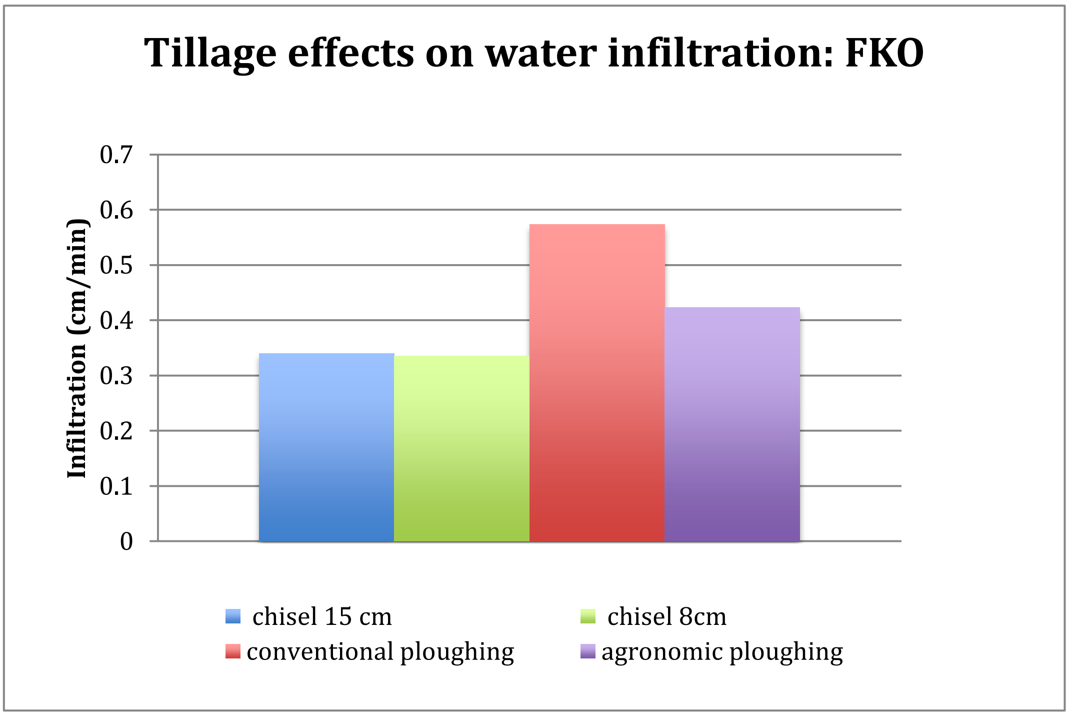

Figure 4-3. The water infiltration of field FKP under different treatment (conventional ploughing, agronomic ploughing and chisel 15 cm and chisel 8cm)

Judging from the result from water infiltration capacity measurement under different tillage treatments in field FKA and FKO, we can find the water infiltration speed of reduced tillage treatment was lower the water infiltration capacity of conventional tillage system. In addition, the ploughing depth was range from 15 cm to 20 cm, which was the active zone of earthworms living in the soil surface and top soil. Earthworms as an ecosystem engineer contribute to better soil quality by decaying organic matter and creating passageways through tunneling towards better water and air circulation. In the other words, the earthworm community would be a bio-method improving the field water infiltration capacity, while still kept soil structure.

Lelystad:

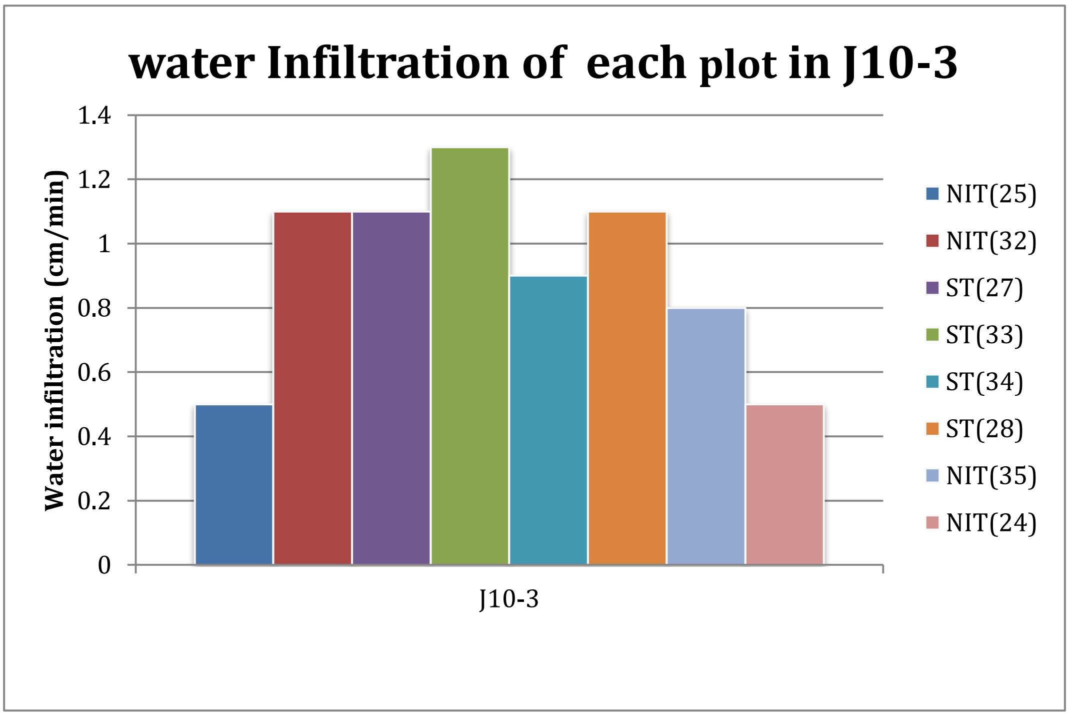

Figure 4-4. Water infiltration of field J10-3

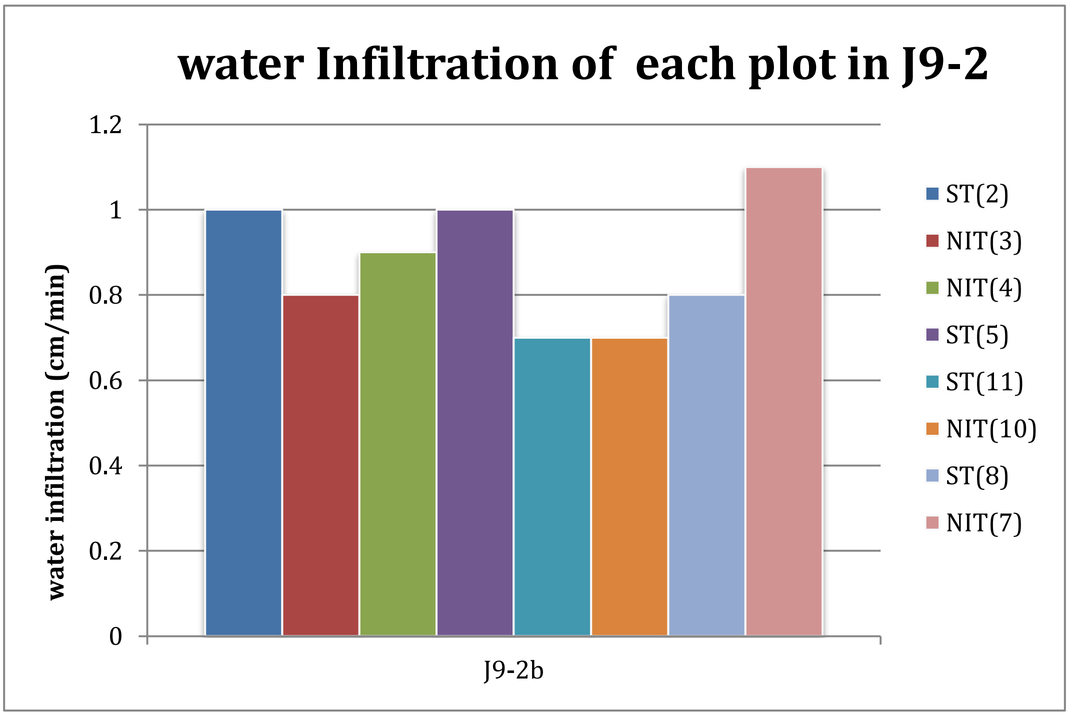

Figure 4-5. Water infiltration of field J9-2b

In Lelystad, there are 2 experiment fields, we measured the water infiltration for 18 plots, and 9 plots for each filed, for every plot, we measured 3 times at the distance of 15m, 30m, and 60m. From the Figure 4-5 and Figure 4-5, we can find that there are 2 different treatments: ST and NIT (The detail maps would attach in appendix).

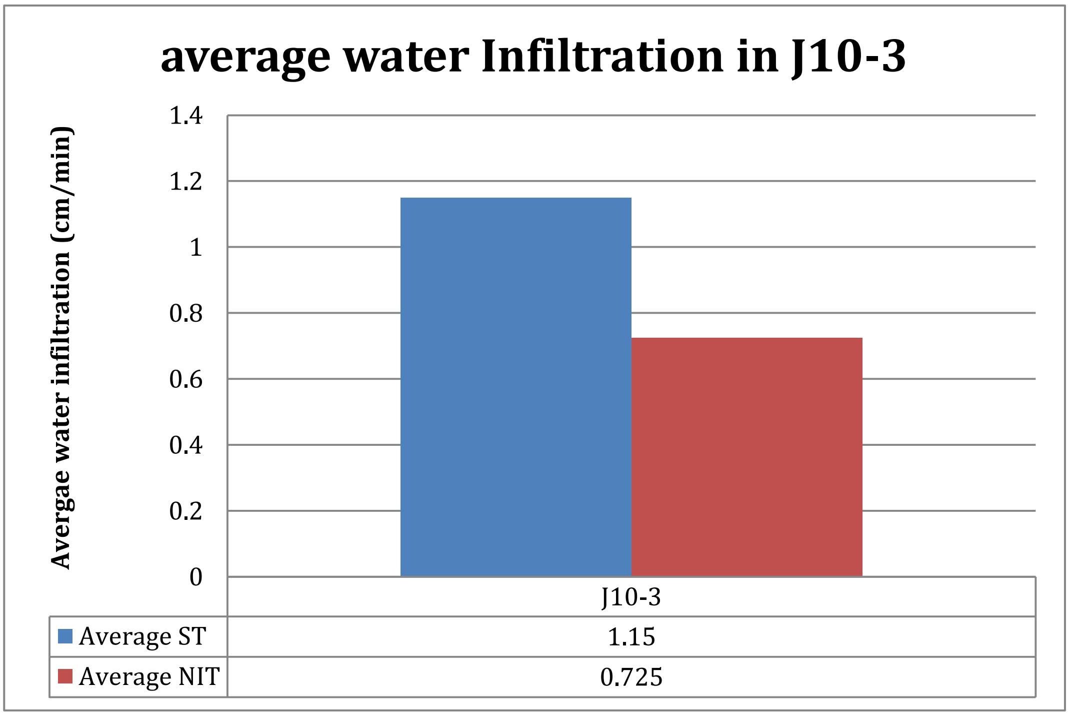

Figure 4-6. Average water infiltration in J10-3

From Figure 4-6 we can find that the average infiltration speed of ST is 1.15cm/min, which is higher than the speed 0.725cm/min of NIT. On one hand, soil in ST treatment was been invert ploughed which would lead to less earthworm, less soil aggregates stability On the other hand, it would also influence the soil structure, which leads to lower water retention of soil. All of those elements would contribute to higher infiltration speed of soil. Compare with ST, NIT system have less plough which means it would have less infiltration speed than ST system.

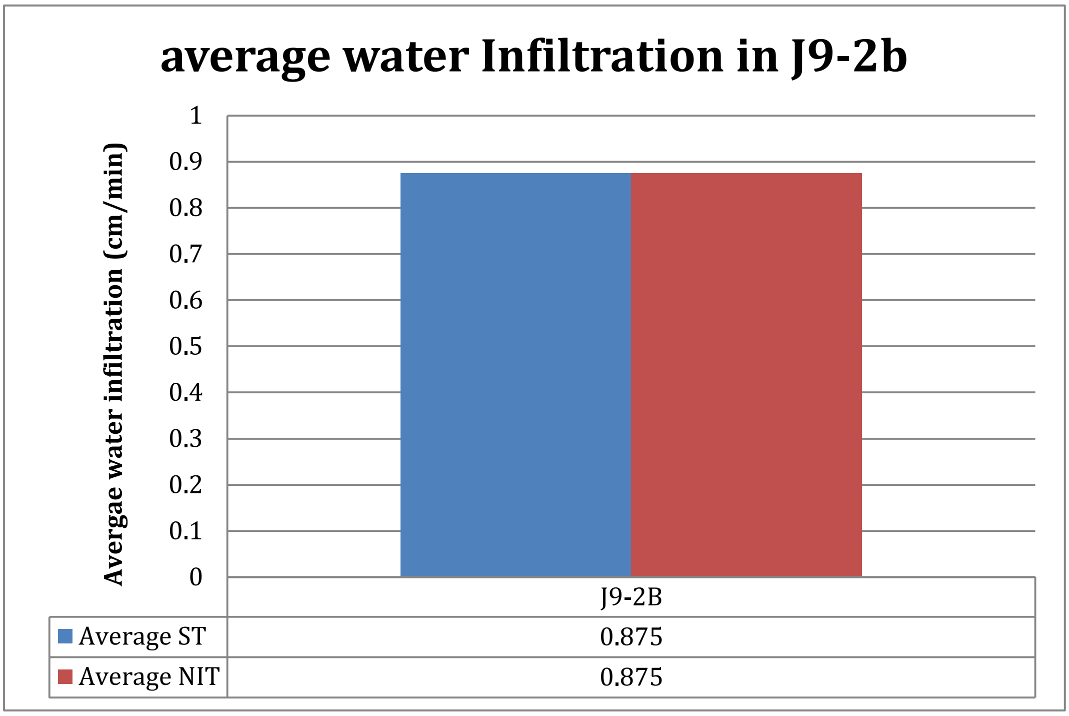

Figure 4-7. Average water infiltration in J9-2b

Figure 4-7 shows the average water infiltration in field J9-2b of two treatments: ST and NIT. We can find that the infiltration speed of two treatments is the same which is 0.875 cm/min. In this case, it is possible that, in some ST plots, the pressures of soil from walking or wheeling would compress the soil, as we known that, the water normally through the soil by macro pores, if apply compress to soil surface would destroy the soil structure, include the macro pores, which lead to soil have less water infiltration speed, and that maybe the reason why ST system only have 0.875cm/min infiltration speed.

Comparing the data from France and Netherlands we can draw a sample conclusion that the water infiltration speed in ST system would higher than in NIT system.

4.2 Soil water retention

Samples are taken from field J10-3 in Leyster, 2011(maps attached in the Appendix), the treatment were applied are: NIT and ST, for each plot, we take samples with 2 depths 0-10 cm and 10-20cm.

After the measurement from sand box and suction plate, samples would oven dried at 105 degree, which defined as a soil that has been dried 105°Cuntil it reaches constant weight and contains no water, in this way, we have the weight of dry soil

Since we have the raw data, we can use the formula to calculate the bulk density, Gravimetric water content and volumetric water content.

Bulk density of soil is usually determined on a core sample which is taken by driving a metal corer into the soil at the desired depth and horizon. This gives a soil sample of known total volume, 100cm3 in our case.

Bulk density = mass of dry soil/ volume

Gravimetric water content = soil water/ mass of dry soil

Volumetric water content= (Gravimetric water content/ Water density)* Bulk density*100%

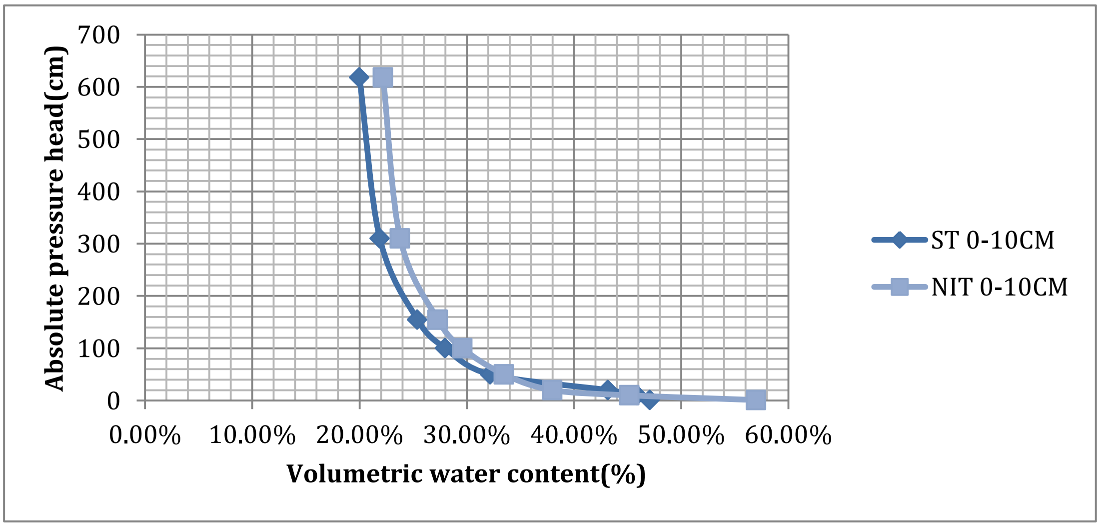

Figure 4-8: Volumetric water content of 0-10cm

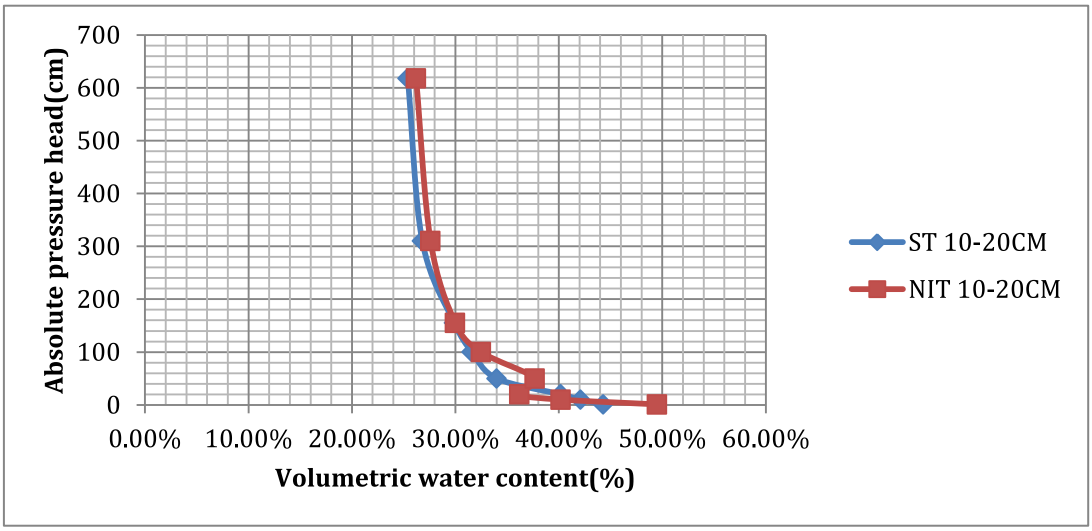

Figure 4-9. Volumetric water content of 10-20cm

The volumetric water content decrease when the absolute pressure head increase, as the Figure shows the same trend for both NIT and ST which is when the higher pressure applied, the lower content of water will lose. From 0-10cm(Figure 4-8), the volumetric water content for ST is 47.1% and for NIT is 57%, with the higher pressure applied, the difference became similar, ST can hold 20% water when the pressure goes to 618cm, and NIT can hold 22.2% in the same pressure. From 10-20cm(Figure 4-9), the volumetric water content for ST is 44.3% and for NIT is 49.5% in 1cm, with the higher pressure applied, the difference became similar, ST can hold 25.4% water when the pressure goes to 618cm, and NIT can hold 26.2% in the same pressure. Compare the two treatments in same depth, NIT always has higher volumetric water content then ST, and the difference is highest in saturate situation, because the NIT treatment has higher aggregate stability and penetration resistance than ST. Compare the two depths, the deeper soil have higher volumetric water content than soil surface, it maybe the mulching effect of crop residue which increase biological activity at surface, thereby loosening the soil (Beisecker, 1994).

4.3 Penetration resistance

Soil penetration resistance (PR) is a measure used to indicate the degree of soil compaction. Recent research efforts have emphasized the importance of PR in determining the critical compaction thresholds for plant growth (Tormena et al., 2007; Reichert et al., 2009)

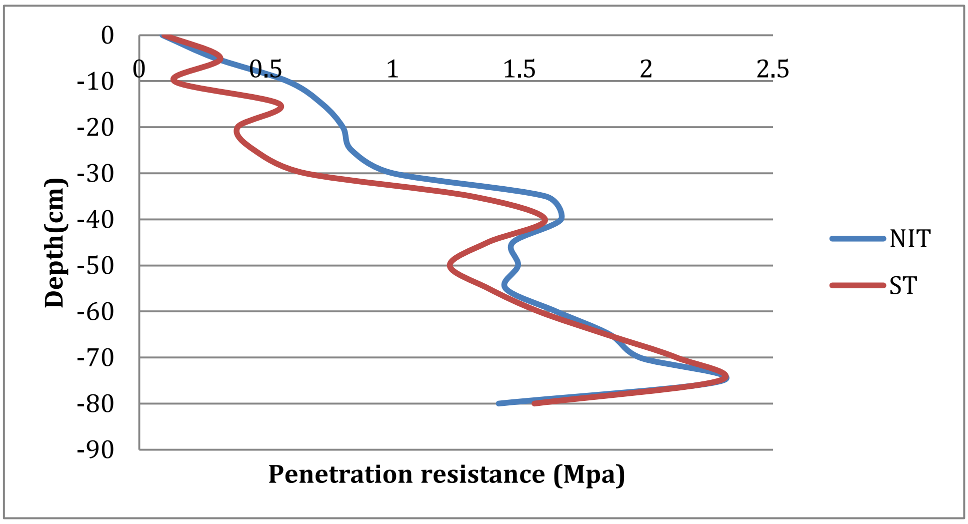

Figure 4-10. Penetration resistance

Soil penetration resistance (PR) is determined for 0-80cm in May of 2012. From the PR curve (Figure 4-10) we can find that both treatments have significant effect on PR varies with depth. The PR for ST (0.099Mpa)is a little bit higher than NIT (0.0915Mpas)at the subsoil (0-5cm), from 55cm-55cm, the deeper soil, NIT shows always higher PR than ST, after that, two treatments back to same PR.

The PR for ST is higher than NIT at surface (0-5cm), which probably because the residue of crop covered the surface, which lead to NIT have loser soil than ST. From 5cm-55cm. NIT is significant higher than ST, there are two reasons for that, first of all, and the ST treatment is plough treatment, which means it would break the soil structure, lead to loser soil condition than NIT, and it also can be supported by our aggregate stability result. Secondly, PR is highly dependent on the soil water content since the bonding of particles is weakened as more water is absorbed (Marshall and Holmes, 1988). It indicates that the water content of NIT from 5-55cm of NIT is lower than ST, probably because the root absorbs more water in NIT compare to ST.

4.4 Soil aggregate stability

Soil aggregates stability measurement is aiming to isolate macro-aggregates versus micro-aggregates and therefore to evaluate resistance versus soil erosion. For example, more macro-aggregates in the soil represent better soil structure and higher resistance for erosion.

Table 1: soil aggregates stability measurement

		Soil aggregates stability (by weight) (%)			
		>2000μm	250-2000μm	53-250μm	<53μm
ST	0-10cm	1.67	24.47	65.50	8.35
	10-20cm	0.58	24.45	67.54	7.43
NIT	0-10cm	3.63	24.37	62.48	9.52
	10-20cm	6.17	30.36	56.30	7.17

The soil aggregates measurement indicates the higher soil stability of NIT system. According to the table, in the soil size fraction >2000μm and 250-2000μm, the percentage of aggregates is relatively higher in the NIT system especially in the deeper layer (10-20cm), which is 6.17% and 30.36% compared to 0.58% and 24.45% in ST system. Besides, in the first two classes, comparing with the upper layer, the aggregates proportion is lower in deeper layer from ST system, while the result is opposition from the NIT system. The inversion tillage system can be the one of the explanations to the case. In the class 53-250μm, the aggregates percentage of NIT system is relatively lower, and more to be significantly in depth 10-20cm, which is 56.3% compared to 67.54% in ST system. The aggregates stability distribution in class <53μm is similar from different tillage system and depth.

The overall soil aggregates stability distribution indicates the NIT system had better soil structure and erosion resistance because of the higher proportion of macro-aggregates in the soil.

4.5 Earthworm density

Lelystad*:*

According to the measurement from Lelystad, the result indicates the earthworm density and tillage system are related and the relationship is representative in different field treatment types.

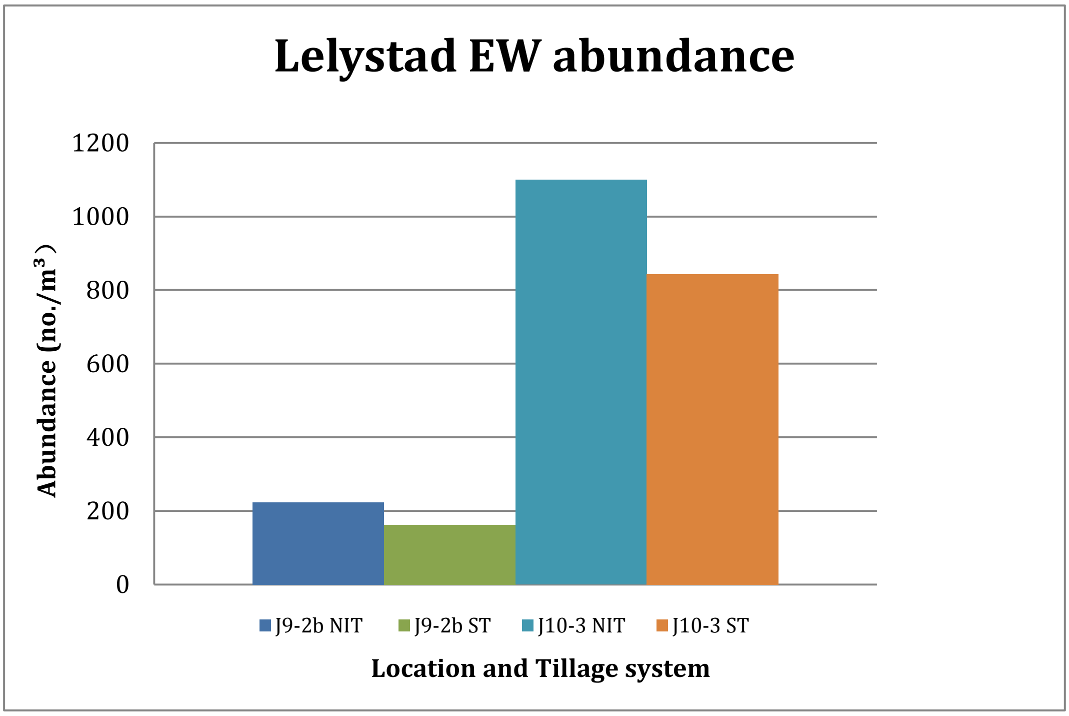

Figure 4-11. The EW abundance comparison of filed J9-2b (integrated treatment) and J10-3 (organic treatment) under NIT and ST system

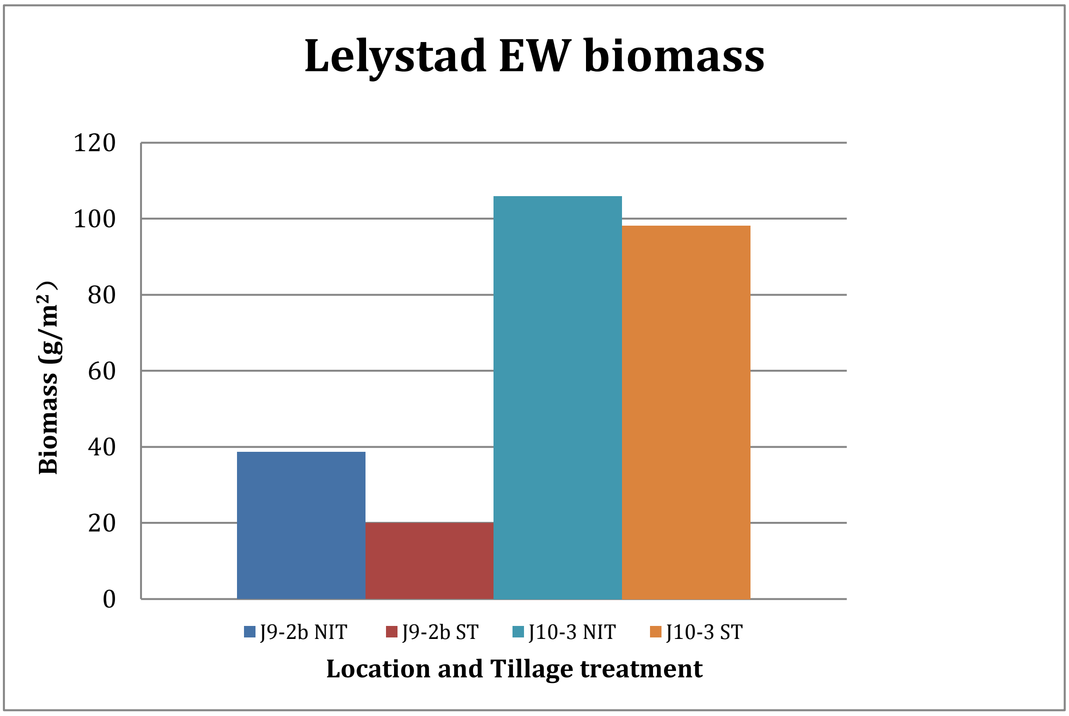

Figure 4-12. The EW weight comparison of filed J9-2b (integrated treatment) and J10-3 (organic treatment) under NIT and ST system

The earthworm density (abundance and weight) from the NIT system is higher than the ST system's (see Figure 4-11 and Figure 4-12). In the integrated treatment field J9-2b, the average earthworm abundance is 222.92 and weight is 38.65 g/m^2 on average, while the earthworm abundance and weight from ST system are relatively lower, which are 162.5 and 19.90 g/m^2 respectively. The measurement from organic field J10-3 shows similar result. The earthworm abundance and weight are 1100 and 105.94 g/m^2 in NIT system and the 843.3 and 98.15g/m^2 in ST system.

The earthworm density measurement under ST and NIT system from organic field J10-3 is matching the measurement from 2009 to 2010, while the result from J9-2b is opposition from past two years' (MSc thesis 2011, Tamila). According to the long-term measurement from integrated field J9-2b, the earthworm density under ST system was higher than measurement from NIT system but current research indicates the higher earthworm density from NIT system. The opposition result from J9-2b can be the hypotheses of influences from plant rotation because the different crops require different tillage intensity during the seeding. However, according to the result from this thesis research, the similar results on earthworm density comparison under same tillage system from different treatment in this case evaluates that the relationship of earthworm density and tillage system is regardless of different filed management types.

5. Conclusions

After the 5 months desk study, field work and measurement, the thesis research evaluates that the soil physical factors and earthworm density are different from ST system and NIT system. Comparing with ST system, the NIT system is higher in penetration resistance, water retention capacity and soil aggregates stability and lower in water infiltration capacity. Besides, the NIT system has higher earthworm abundance and biomass than ST system.

The research outputs are based on the measurements from different field treatment types (integrated and organic), tillage treatment (NIT and ST) and experimental sites (Lelystad and Kerguéhennec). The similar results from different agricultural conditions give the idea about the relations on soil physical factors and earthworm density and tillage system is representative to different field treatment types and regions.

Based on the thesis research results, NIT system is firstly presenting better capacity on erosion resistance because of the higher soil aggregates stability. The lower water infiltration capacity and higher water retention capacity indicates the better solution to irrigation system. Higher earthworms density represented from the NIT system is contributing to the positive relations with agricultural activities and ecosystem.

In addition, the thesis research also suggests the interesting topic on relations between crop rotation, soil physical factors and earthworm density in further research. Different crops seeding require different tillage intensity. Besides, crop growth and residues are also influencing on the soil physical factors and nutrient.

Overall, biased on our thesis research, NIT system promotes sustainable solution to the irrigation system, better resilience capacity to the extremely weather conditions and further benefits the agro-ecosystem service.

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Lastly, we offer our regards and blessings to all of those who supported us in any respect during the completion of the thesis.

Peter and Tony

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Appendix

Appendix 1: Participants

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Appendix 2: Time schedule

Events	February	March	Apil	May	June	July
Documents reading	P T					
Proposal	P T					
Data collction (France)		P+T				
Lab work		P T				
Data collction (Netherlands)			P+T			
Lab work				P+T		
Data analysis		P T		P T		
Final thesis writing					P T	
Final presentation					P T	

Appendix 3: Field FKA

FKA site - Trial plan

10 plots (12 m X 25 m) X 3 blocs -> 30 plots in total

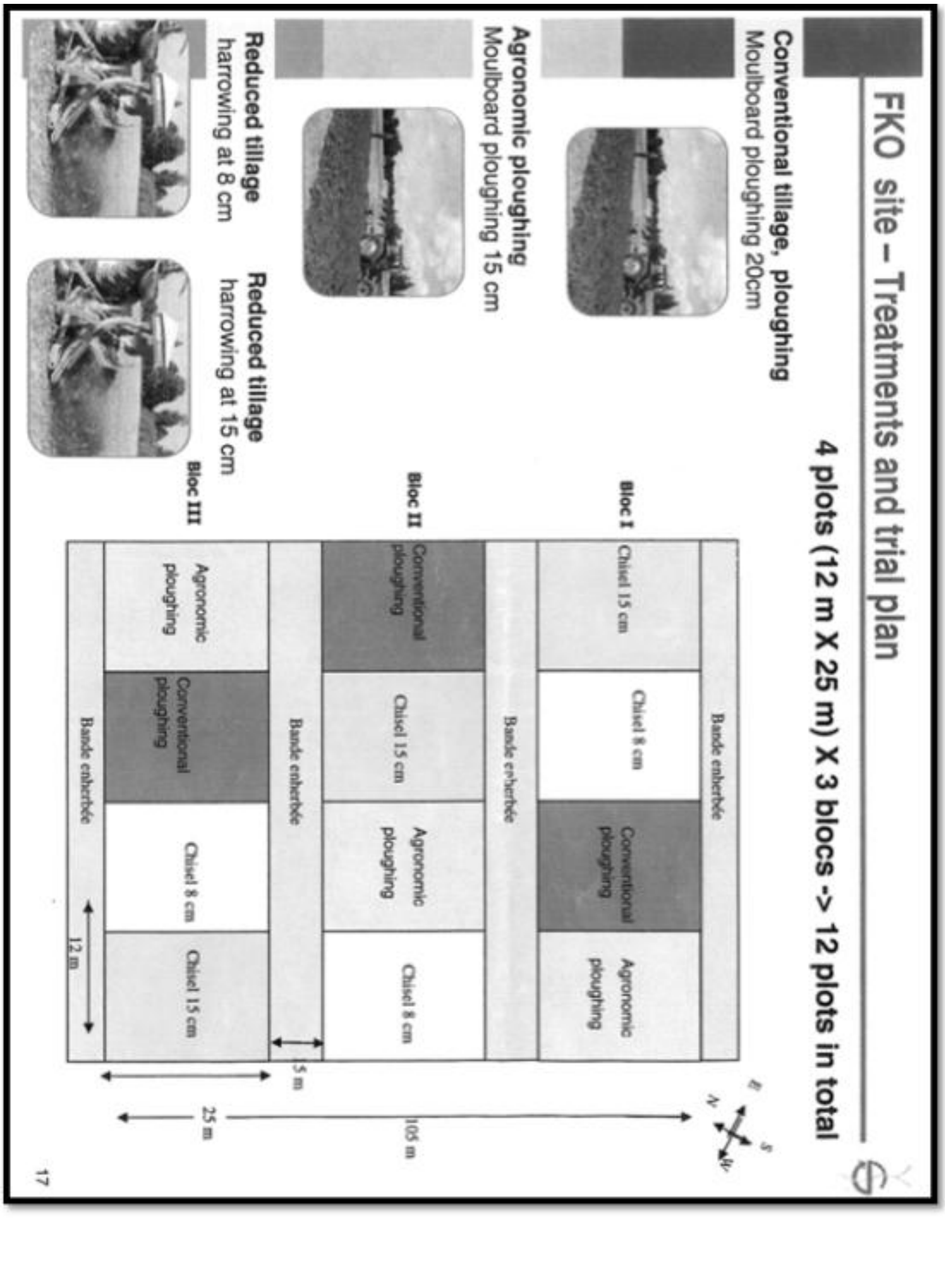
Bloc 1	RT PM	RT M	NT PM	NT M	P M	P PM	P M-FB	P LP	RT M-FB	RT LP
Bloc 2	P M	P PM	RT M	RT PM	NT M	NT PM	RT LP	RT M-FB	P LP	P M-FB
Bloc 3	NT PM	NT M	P PM	P M	RT PM	RT M	P M-FB	P LP	RT M-FB	RT LP

P: Ploughing **RT**: Reduced tillage **NT**: No till

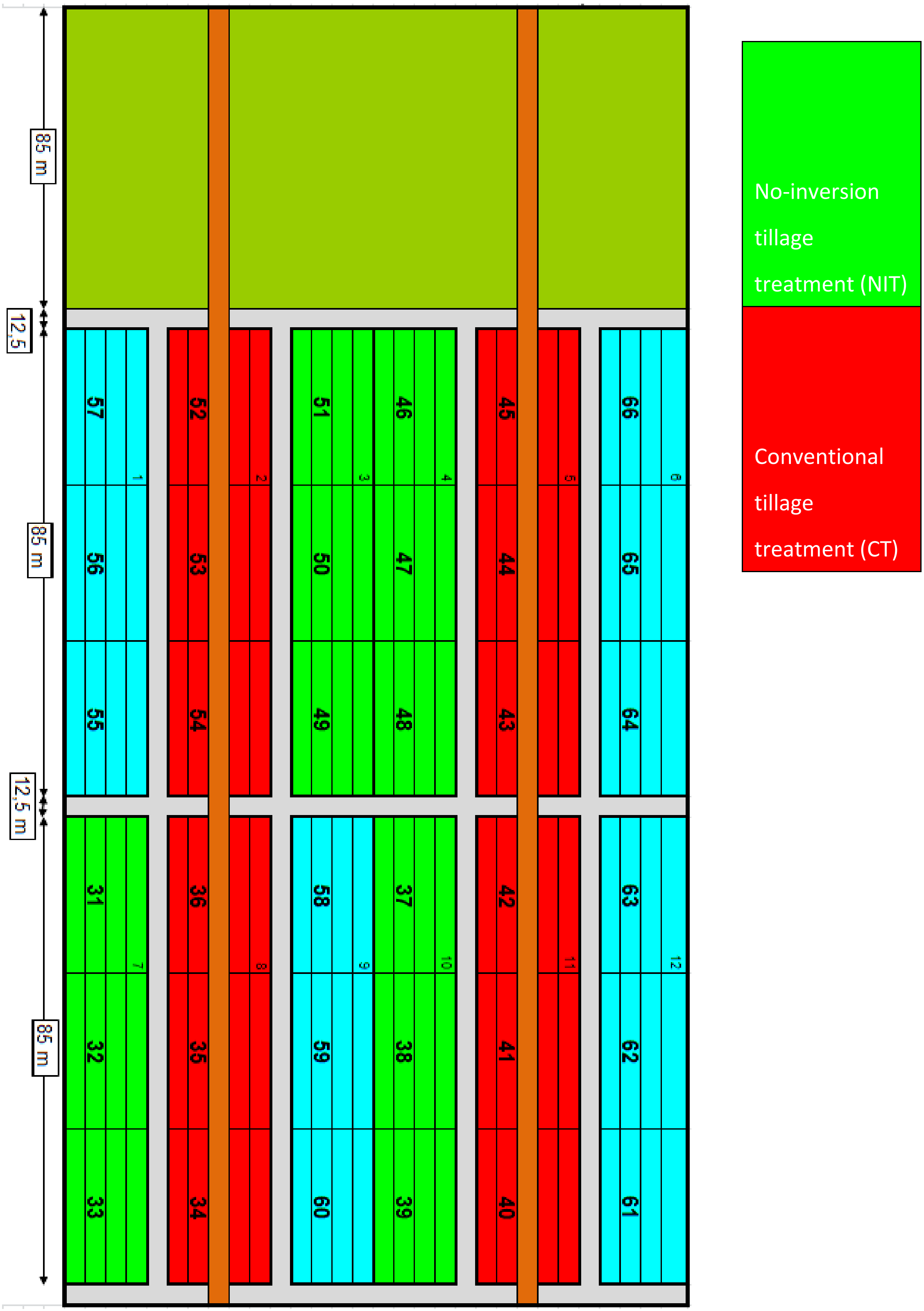
M : mineral, **PM**: poultry manure, 6 t /an **LP** pig manure, 25 m3/an **M-FB** :mineral and cattle manure 40 t every 4 years

1

Appendix 4: Field FKO



Appendix 5: J9-2b



Appendix 6: J10-6