No Till Improves Soil Functioning and Water Economy.

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Abstract: The No Till system is very effective to increase soil water infiltration, to reduce evaporation from soil and also to reduce water run-off. The water availability for crops is increased, offering the opportunity to improve general soil functioning and crop performance. The principles are equally useful for both rain-feed or irrigated cropping condition. Under rain-feed, No Till greatly contribute to minimize the yield impacts caused by water stressing periods allowing to obtain higher and less variable crop yields. Under irrigated condition they can significantly contribute to reduce the amount of water needed to develop a given crop. These No Till beneficial characteristics are associated with other important positive impacts. Among them, the reduction of the water run off and the consequent reduction –or avoidance- of soil erosion, is a relevant one. Also the crop residues covering the topsoil create a favourable environment for a significant increase of the biological activity that further improves the soil and general agro-ecosystem functioning. **Keywords**: No Till. Crop residues. Covered topsoil. Water availability for crops.

Water Economy

In central areas of the Sub-Humid Pampas of Argentina, when comparing No Till with conventional tillage, it was found that an average of around three “extra” inches of crop usable water could be annually gained into the soil profile, Dardanelli (1998). The reason for this water economy improvement, could mainly be found on an increased soil water infiltration as well as on a diminished evaporation by means of topsoil covered with crop residues. On Dardanelli measurements, and for both No Till and conventional-plough till, the value of the coefficient that relates the daily rain with the water that effectively gets into the soil profile -effective rain-, normally decreases with the increase of the intensity of the daily rain. However, the higher the intensity of the daily rain, the greater the difference of the coefficient in favour of No Till. Under conventional tillage it is very frequent to find effective rain coefficient values of 0.5 or even lower while for No Till, values of 0,7 are common. On Fig. 1, constructed with data reported by (Dardanelli 1998), the values of the effective rain for different daily rain intensities can be found and the values of the coefficient or relationship between the two variables can be derived.

Besides depending on the cropping system (No Till or Conventional), and on the intensity of the daily rain, the value of the coefficient also largely depends on other natural and No Till “acquired” characteristics as:

- The soil type (texture and structure)
- The slope,
- The natural and No Till acquired porosity.
- The soil permeability.
- The rotation
- The amount of crop residues covering the top soil,
- The type of crop residue,
- The years under no till,
- Others.

Several years ago, and when No Till was mostly on an experimental stage in Argentina, (Totis de Zeljcovich 1984) in a trial that compared the water efficiency use for corn cultivated under no till and conventional tillage, had found a highly significant better water efficiency use for the no till treatment. The figures were 14.5 Kg. of grain produced for each mm. of actual evapo-transpiration (A.E.T) under no till, (equivalent to 0.368 Ton of grain/inch of water actually evapo-transpirated), and 10.6 Kg. of grain for each mm. of A.E.T (equivalent to 0.269 Tons of grain/inch of water actually evapo-transpirated) for conventional tilled land. Fig. 2. This finding represents a thirty seven percent increase in the water efficiency use under no till compared to conventional tillage.

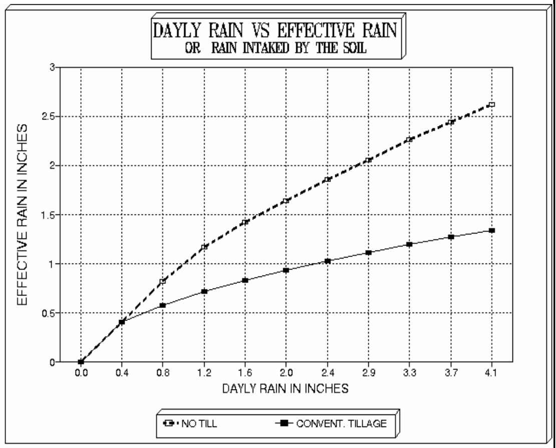


Fig.1. Source (Dardanelli 1998). Daily Rain Vs. Effective Rain for a No Till and a Conventional Till

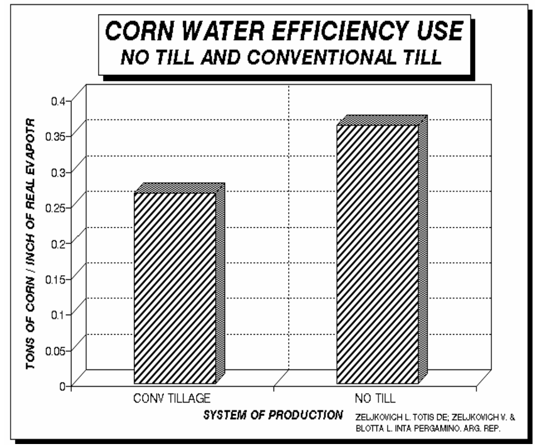
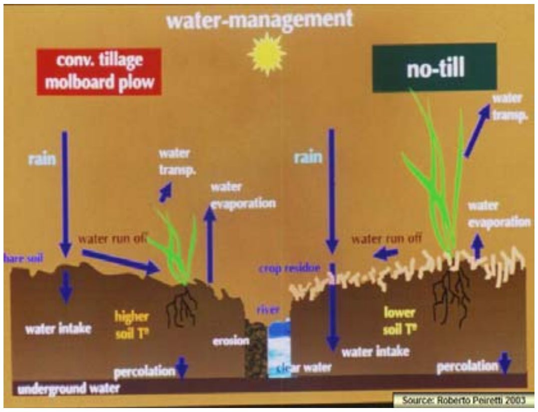


Fig.2. Source (Totis de Zeljcovich 1984). Corn Water Efficiency Use under No Till and Conventional Till

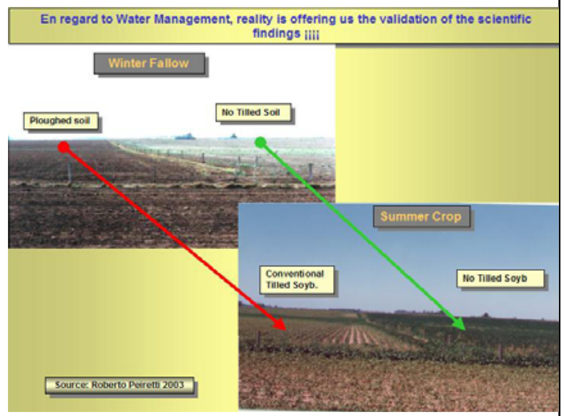
For corn and some other crops grown on some long term (fifteen years) No Till farm operations, nowadays we have some empirical evidences that show higher values for the water efficiency use than that reported by Totis de Zeljcovich in 1984. In the case of corn, some calculations indicate that the figures could be as high as 20 to 25 kg of grain per each millimetre of real evapo transpiration. However, further studies and experiments are needed to validate this empirical observations and corresponding calculations from data and observations obtained at the farm level and for those long term No Tilled and improved agro-ecosystems.

Based on the average “extra millimetres” that No Till allows us to gather into the soil profile (discussed at the beginning of this Water Economy point), and for the average water efficiency use for different crops raced on the central area of Argentina, we can make some simple calculations and compute the “extra grain” that could be produced by using those gathered “extra millimetres” of crop available water. On the case of corn the figure for the “extra grain” that could be produced can be estimated on one and a half ton per hectare year while for soybean and wheat the figure could be around half a ton per hectare year. Besides the enlarged water capturing ability, a soil well covered with crops residues also reduces the water losses due to water evaporation directly from the soil profile. This is also a phenomenon that significantly contributes to the greater amount of soil water availability for crops that can be achieved under no till. The enlarged soil water capturing ability developed by No Till is also very useful to diminish the water run off and consequently to reduce the eroding forces and contamination capacity. Under rain-feed crop condition, the No till extra gathered millimetres, can improve crop performance when rains are delayed. Within certain limits, the extra millimetres gathered into the soil can prevent the crop to reach the PWP (Permanent Wilting Point). This is particularly important while cropping on the marginal sub-humid to semi-arid areas where soil water holding capacity and rainfall are lower that in humid ones. Also the phenomenon is important for these marginal or limited areas, because the rainfall is not only lower if not more erratic on its occurrence. Taking into consideration this water system benefit, with no till the agricultural boundaries can be somehow extended into this limited areas. Such extensions must however be carefully considered. On Pic. 1, the mayor soil-water features functioning relationship and No Till benefits, are conceptually and schematically and conceptually represented.

The improved water intake capacity, combined with a minimized direct soil surface evaporation, is the mayor factors that explain the possibility of gathering those precious extra millimetres of available water. On Pic. 2, we can see all these phenomena working together on a real farm condition suffering from the lack of appropriate rain. While developing a crop under regular farming condition, those extra millimetres makes “a big difference” at the time of overcoming a water stress period. The negative impacts on potential yield can be minimized. On the limits, the extra millimetres can even represent for the crop the difference between staying alive or dying. On Pic. 2, (a composite of two pictures taken by myself, one during the winter and other during the summer), two paddocks side by side (divided by a fence) can be seen. The one on the left of the fence was managed under conventional till while the one on the right was managed under the No Till principles. On the upper left picture, the paddocks during the winter time can be seen, while on the lower right one, we find the same paddocks during a summer and in the middle of a severe water stress period. In both cases soybean crops were raced under rain-feed condition. While the left paddock, managed under conventional gave a negligible yield – was even not harvested on most of the area-, the one on the right -under No Till- yield two tons of grain per hectare. If we take into account the drought it have to withstand during the growing season it should still be considered as a good yield.



Slide 1. Schematic Water-Soil functional features. Source: Roberto A. Peiretti 1996.



Slide 2. Side by Side No Till-Conventional Till Soybean Comparison. Source: Roberto A.Peiretti 2000.

Some other benefit derived from the better water management achieved by NO Tilling and covering the soils.

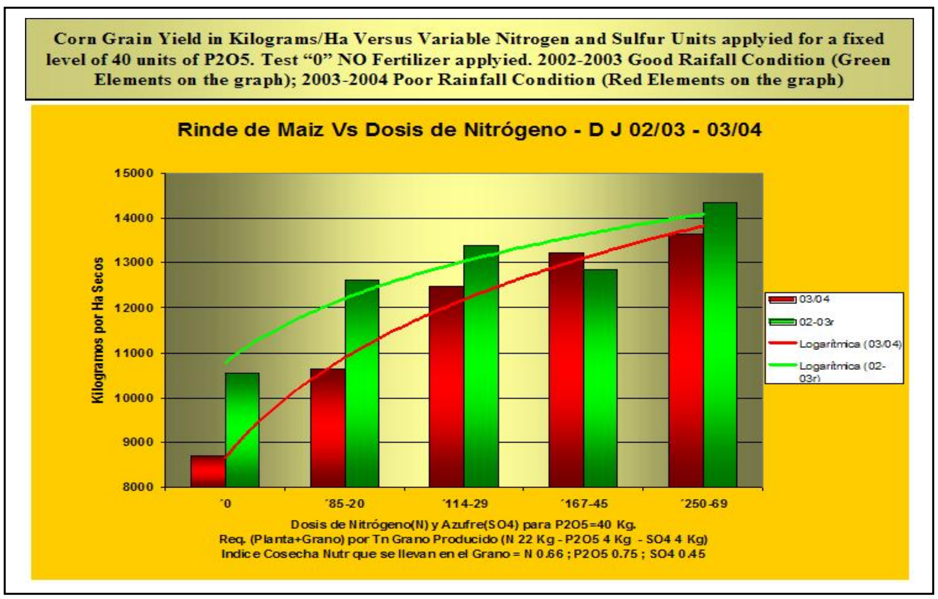
a.) Maximizing corn yield and minimizing inter annual yield variability.

Inter annual variability of rainfall for a given area, is one of the mayor factors on which also inter annual variability of crop yield depends. By having more water captured into the soil profile for a given amount of rain, we are cleared to aim for a higher and more consistent (less variable) yield target. (Check information and results included on (Peiretti 2001). Those extra millimetres of crop available water that No Till is offering, allow us to redefine the yield target. While managing the farming operation under a systemic view and taking into consideration the selected yield target, we should then adjust the “level of utilization” of several other inputs or system components. Just as an example the systemic managerial strategy, among others, we would have to select the right combination and level of nutrients to be applied as fertilizers with the most suitable genotype for the agro ecosystem condition. Also, this decision would have to be combined with a correct weed management strategy, with the usage of the most appropriate plant density, and planting date, with a proper strategy for insect and diseases control; etc.

A farm level trial was run for the growing seasons 02-03 and 03-04. Corn crop from which the data and results (shown on Pic. 5 and 6) were obtained, was managed under a No Till and a systemic approach. The latest and most modern technology was utilized to develop the crop. For each of the growing seasons, the trial was established on nearby paddocks. These paddocks have the same type of soil and were managed under No Till for the last 15 years. On the growing season 2003-2004 and even a quite severe restriction on the rainfall was present, still a fair good grain yield and reasonable response for the variable fertilizers rates was obtained. The results constitute a reasonable empirical evidence of the usefulness of No Till to overcome a water stress period during a given growing season when cultivating corn utilizing a No Till systemic approach.

On Pic. 4, the yield curves for both cropping seasons versus different nitrogen and sulphur rates for a fix phosphorous rate (including the “0” level test plot for both seasons), can be seen. The results of the trial shown on Pics. 4 and 5, to some extent are useful to attempt to demonstrate the existence of a positive interaction between the “extra millimetres gained by No Till” and the possibility of improving the crop performance. Green lines and bars represent the results for 2002-2003 growing season while red ones represents growing season 2003-2004. While on copping season 2002-2003 the effects of the extra millimetres was useful to maximize corn yield response to a higher utilization of nutrients, on cropping season 2003-2004 with a restricted rainfall the extra millimetres were useful to prevent a drastic yield fall and still to get a response for the higher fertilizer rates and to collaborate to diminish the inter annual yield variability. On

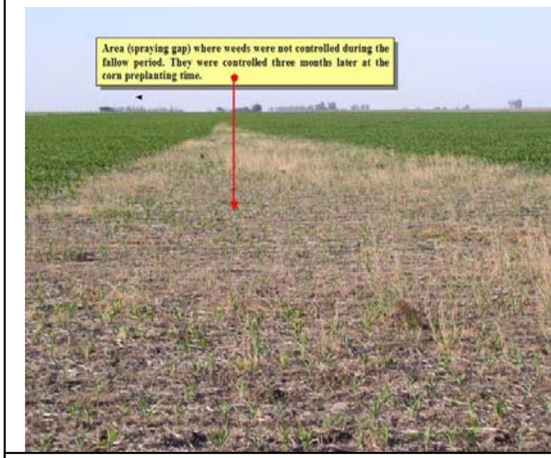
Pic. 5. we can see the how the extra millimetres were useful to get a response on corn ear size. This is somehow a repetition of the positive No Till effect that was already shown on Pic. 2 for soybean on a dry year.
For both seasons 2002-2003 and 2003-2004, the corn for the trial was cultivated under an almost perfectly covered soil condition. On Pic. 6, and for season 2002-2003, the crop and soil covered condition, can be clearly seen.
Picture 7, was taken during growing season 2003-2004 (restricted rainfall), and shows a paddock located on the same area where the trial was settled. It is included on this paper to exemplify the need to properly manage the system all year round. On it, we can see the negative impact that can cause a mistaken weed control program. A spraying gap during the winter fallow time show us the importance of controlling weed at the right time as a way to better manage the water economy. There is no a fix recipe related to when and how to control them (it will depend upon a given agro ecosystem condition and the strategy applied), but in any case the experience shown on Pic. 7, demonstrates how important the issue is at improving water economy. We can see the negative impact of letting weeds to vegetate longer that desired (the effect could be appreciated inside the winter spraying gap). The weeds within the spraying gap, kept alive and vegetate for a longer period than for the rest of the field where they were timely and correctly sprayed and controlled. The weed control within the spraying gap, only took place two months later at pre-planting time. They were able to consume more water from the soil profile preventing the maximization of the water saving during the fallow period. For the agro ecosystems of the region where the trial was settle, it seems that the best strategy for planting corn appears as that aimed to capture (and save) into the soil profile, as much water as possible for the next crop at least for years of rainfall lower than the average.



Pic. 4. Corn Yield Response for variable N and S rates and for two seasons 02-03 (god rainfall), and 03-04 (low rainfall). Source: Roberto A. Peiretti 2004.

Pic 5. Growing season 03-04. (Water restricted). Corn ear size for test plot and for N and S variable application rates."0","85" and "115" unit of N. "0","20" and "29" s and "0", "40" and "40# for P2O5 and. Source: Roberto A. Peiretti. 2004.

Pic.6. No Tilled Corn on well covered soils- 2002-2003 growing season. Source: Roberto A. Peiretti. 2003



Pic.7. Negative Impact of a Spraying Gap
Corn -Growing Season 2003-2004. Source: Roberto A .Peiretti 2003

b.) Moving the boundaries into a more rainfall limited area.
The water economy improvement that No Till offers, constitutes an opportunity to move the boundaries of rain-feed crops into lower rainfall areas. In Argentina, we do have quite a large number of potential “marginal rainfall areas” into which annual crops had been successfully incorporated by utilizing a proper systemic No Till management. When the limit of water availability on the soil for a given area is approached, the importance of properly managing the crop under No Till can be clearly seen. While cropping on these conditions, those extra water millimetres that No Till can offers, make a big difference. On these areas, the general agro ecosystem management and crop strategy under No Till should be aimed to this target.
When we move into irrigated crop condition, the utilization of No Till principles can also help by reducing the need of the millimetres to be irrigated. This goal should be considered as an achievable one, and in fact, empirical observations are clearly indicating the possibility of obtaining this benefit.
Even the statements and findings mentioned on this point (b.) are mostly derived from empirical evidences obtained on real farming operations, the experimental results reported on the bibliography of this paper support them.

c.) Better soil health and water born soil erosion control
The absence of soil tillage and the consecution and maintenance of crop residues permanently covering the topsoil has a high relevance for a proper No Till system functioning and for the achievement of several other soil and agro ecosystem functional benefits. No Till and the soil covered condition that the system demands, significantly helps to reduce the amount and speed of water run-off diminishing the erosion forces and at the same time diminishing the sediments and solutes that are regularly carried by it. Also they create a much more soil favourable environment within those first millimetres of the soil profile where a large amount of chemical and microbiological activity takes place. The presence of glomalin, a stable protein that is a by-product of a special type of fungi, is largely enhanced by this no till environment (Wright**, 2001).** This author had also reported a strong correlation between the content of glomalin with the stability of soil aggregates and resistance to erosion. This desirable physical soil condition and the mechanical barrier that the crops residues represent, constitutes key issues to prevent the soil surface sealing that occurs when raindrops hit the nude soil surface that we regularly found under conventional till condition. Under No Till soil surface keeps in good shape to be able to capture the raindrops incorporating them into the soil profile. (No Till improved water capturing capacity). The general topsoil aspect of a well-rotated well-covered No Till soil, can be seen on Pic. 7. Also within these first millimetres of soil where a special and more humid No Till environment is more frequently found, the activity of a large number of microorganisms is greatly enlarged. Their activity speed up the decomposition of the crop residues and consequently speed up the nutrient cycling process. Regularly this phenomenon contributes to a better soil functioning and general crop productivity. Also a noticeable increase of the “meso fauna” collaborates to further improve the soil functioning and water capturing ability by creating a very effective “net” of the so called “bio pores”. Even more scientific studies and measurements are

needed on these issues, on Pic. 7., we can appreciate how these phenomena are present. They can be easily found at the farm on those long no tilled soils.

Pic.7. Soil covered showing a good aggregation on the first few millimetres. Souce: Roberto A. Peiretti 2004

Pic.8. Earthworms on a 15 years No Tilled soil. Source: Roberto A. Peiretti 1999.

Conclusions

On soil properly managed utilizing the No Till principles for the last fifteen years, significant progresses had been achieved on both water management and general soil and agro ecosystem functioning. While in a number of cases these progresses obtained in real No Till farming scenarios had been in coincidence with the result of several studies, further studies are needed to fully explain the complexity of the agro ecosystem functioning. Even so, the empirical evidences and the good results obtained on real farming operation, seems to indicate that the full and correct utilization of the No Till system principles along with a systemic approach, can significantly contribute to improve the water-soil-plant multiple relationship and at the same time be improving the general agro-ecosystem productivity and sustainability.

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