Transdisciplinary integration and interfacing software in mechatronic system for carbon sequestration and harvesting energy in the agricultural soils for rewarding farmers through green certificates

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Abstract. In this article we will present a transdisciplinary approach to carbon sequestration in agricultural soils. The software provides a method proposed to measure the amount of carbon that can be captured from different soil types and different crop. The application has integrated an intuitive interface, is portable and calculate the number of green certificates as a reward for farmers financial support for environmental protection. We plan to initiate a scientific approach to environmental protection through financial incentives for agriculture fits in EU rules by taxing big polluters and rewarding those who maintain a suitable environment for the development of ecological and competitive agriculture.

1. Introduction

Chemical element that has the greatest importance in the world is C (carbon). Is found in all organic substances. He play a very important role in developing and sustaining life on Earth and by adjusting the amount of the atmosphere may improve environmental conditions. Through photosynthesis, plants can transform CO₂ and H₂O in carbohydrates and O₂ (oxygen). This process is bio-energy and nuclear plant uses solar energy as the main fuel. That is, plants produce carbon-containing organic substances from water and inorganic carbon in the presence of light. Our idea is to integrate the technological process in agriculture as a source of carbon sequestration in plants and soil and to financially reward farmers by measuring the amount of carbon sequestered annually. Such amount may be converted to measured and these green certificates can then be redeemed. CO₂ in air, water and soil is a mineral nutrient needs of plants. An important consequence of this feature is to release O₂ molecule.
Photosynthesis takes place at night and the plants just breathe. During 24 hours resulting in breathing CO$_2$ production is less than that of O$_2$ resulted from photosynthesis during the day. Plants produce O$_2$, yet are large sources of CO$_2$ (as converted). During photosynthesis, plant materials possess a number of mechanisms typical to decarbonate dioxide fixation (Figure 1). In plants, such as photosynthesis is determined by the number of carbon atoms in an organic molecule formed during the first CO$_2$ fixation. Humification is the degradation of organic matter of roots, crop residues, leaves falling and the results produce a certain amount of C and humus, which gives the degree of soil fertility. Humus is formed as a result of biochemical processes of transformation of dead organic substances. In fact, the process is completed by the action of soil bacteria. Soil organic carbon is the largest reservoir in interaction with the atmosphere and is estimated to between 1500 and 2000 Pg C to a meter deep (2450 about two meters deep). Inorganic carbon has a somewhat lower value Pg 750, but is captured in more stable forms, such as carbonates. Vegetation (Pg 650) and atmosphere (750 Pg) sequestres considerable amounts lower than the ground. The flow of terrestrial carbon or organic carbon in soil and atmosphere is important and can be positive (sequestration) or negative (CO$_2$ emission). We can say that the plants and the soil is humus huge reserves of carbon dioxide and from this point of view plays an important role in the heating processes of the soil but it has great importance for soil fertility preservation at a satisfactory level.
2. Storage of CO₂ [3]
Terrestrial ecosystems and oceans take much of the CO₂ (pools) but about 3.4 Gt C accumulates in the atmosphere each year. CO₂ is dissolved in water and thus reaches rivers, lakes, seas and oceans, which is in this way huge storage tanks of CO₂. The majority (2/3) of terrestrial carbon is found in soil and roots. 1500 Gt C estimated organic world, some more protected against decomposition. Reserve C below the ground in forests, permanent grassland and other permanent ecosystem (mountain areas) remains almost intact ecosystem as long as the changes do not suffer (Figure 2). There is no guarantee that aquatic and terrestrial mainframe systems mentioned above remain active in absorbing C when limits are reached. There are big differences between arable soils and grassland soils, in terms of their storage capacity for carbon.

The first 10 cm of the basement levels are important to C. When performing work on grassland soils in arable soils for processing in the first few years after conversion lost almost half of reserve C. This phenomenon is well highlighted in the experiment conducted at Rothamsted-Johnston Highfield [1]. The transformation of arable land into grassland, requires several years (more than 50) to return to the same level the percentage of C of a permanent grassland. Garwood et al [2] demonstrated clearly have the first 10 cm in the basement of a grassland containing a percentage of C nearly double compared with arable land.

3. Calculation deposits C
Samples must be taken from different depths. For a soil arable, they must be at 20, 40, 60 and 100 cm and soils grass: 10, 20, 50 and 100 cm (because most concentration of C was found in the top 15 centimeters basement) [4], [5], [6], [7].

C in organic substance (MOC) of soil is distributed by an exponential curve:

\[ C_z = C_b + (C_0 - C_b) \cdot e^{-k \cdot z} \]  

(1)

\( C_z \) = density C (g MOC.cm\(^{-3}\) ground) at depth z.
\( C_0 \) = density C to a depth 0
\( C_b \) = density C at a depth b
\( k \): constant.

The density to be calculated: % C (g MOC.g\(^{-1}\) sol) x density of soil \( \rho_d \).

From this expression (1) to calculate the constant k, which expresses the C exponential decrease with depth. A big factor C corresponds to a decrease rapidly during the first 10-20 cm soil depth. The study dealt factor k Mestdagh I. [8] in his doctoral thesis, and the influence of agricultural practices on soil density and storage MOC. From this study it can be concluded that the Belgian soils that are heavy texture (clay) contain 50% more MOC and 25% more compared to sandy soils and limestone.

By integrating expression (1) between 0 and 100 cm\(^{-1}\) C ha get values up to 1 m depth (Figure 3):

\[ \int_{0}^{100} (C_b + (C_0 - C_b) \cdot e^{-k \cdot z})dz = 100 C_b - k^{-1}(C_0 - C_b)e^{-k \cdot 100} - (-k^{-1}(C_0 - C_b)e^{-k \cdot 0}) \]

\[ = 100 C_b + k^{-1}(C_0 - C_b)(1 - e^{-k \cdot 100}) \]

\[ c_{0-100 cm} = (1 - e^{-k \cdot 100})(C_0 - C_b) \cdot k^{-1} + 100 C_b \]
In Article 3.4 of the Kyoto Protocol additional anthropogenic activities (human induced) give opportunity to be calculated as CO₂ storage pools:

\[ \Delta GES (2008-2012) - 5 \times \Delta GES (1990) \]

(2008-2012 = periodic 5 ans)

(GES: greenhouse gas)

For arable and grassland soils is accepted additional human activities (agriculture) such as recultivation of vegetables, reseeding grassland management systems etc. It is estimated that deposits C meadows between 3% and 26% of global deposits. C rainforest reserve is 19%.

![Figure 3. The concentration of C at different depths in the soil](image)

4. Experimental measurements of carbon deposits

Soil samples were taken from Vețel town located 30 km from Deva, Hunedoara County, Romania. They covered all soil types and crops where samples were taken. Laboratory analysis show following data [6] (Table 1, Table 2).

**Table 1. Laboratory analysis for soil MOC (town Vețel)**

| Sample No. | Sample | Depth | MOC  |
|------------|--------|-------|------|
| 1          | A0     | 10    | 2.15 |
|            | C1     | 11    | 2.03 |
|            | C2     | 12    | 1.85 |
| 2          | A0     | 15    | 1.75 |
|            | C      | 16    | 1.65 |
| 3          | A0     | 18    | 1.53 |
|            | C      | 19    | 1.46 |
| 4          | A0     | 20    | 1.42 |
|            | C      | 21    | 1.42 |
|   |   |   | MOS  |
|---|---|---|------|
| 5 | A0 | 22 | 1.39 |
|   | C  | 23 | 1.39 |
| 6 | A0 | 24 | 1.37 |
|   | C  | 28 | 1.36 |
| 7 | A0 | 29 | 1.35 |
|   | C  | 30 | 1.35 |
| 8 | A0 | 32 | 1.32 |
|   | BV | 33 | 1.31 |
| 9 | A0 | 46 | 1.29 |
|   | BV | 51 | 1.29 |
|   | C  | 53 | 1.28 |
|10 | A0 | 55 | 1.22 |
|   | BVW| 62 | 1.22 |
|   | CW | 65 | 1.17 |
|11 | A0 | 69 | 1.17 |
|   | BTW| 70 | 1.15 |
|12 | A0 | 71 | 1.13 |
|   | BTW| 86 | 1.07 |
|   | C  | 90 | 1.05 |
|   | C1 | 92 | 1.02 |

**Figure 4.** Values MOS at various depths in the soils of the area Vețel village (Table 1)
Table 2. Laboratory analysis for soil carbon deposits (town Vețel)

| Sample No. | Sample | Depth (Deph) | Carbon% |
|------------|--------|--------------|---------|
| 1          | A0     | 12           | 6.40    |
|            | C1     | 14           | 6.10    |
|            | C2     | 16           | 5.48    |
| 2          | A0     | 18           | 5.22    |
|            | C      | 22           | 4.85    |
| 3          | A0     | 24           | 4.70    |
|            | C      | 26           | 4.24    |
| 4          | A0     | 28           | 3.80    |
|            | C      | 30           | 3.45    |
| 5          | A0     | 34           | 3.20    |
|            | C      | 42           | 2.90    |
| 6          | A0     | 52           | 2.60    |
|            | C      | 62           | 2.30    |
| 7          | A0     | 64           | 2.20    |
|            | C      | 68           | 2.05    |
| 8          | A0     | 70           | 2.00    |
|            | BV     | 72           | 1.90    |
| 9          | A0     | 74           | 1.70    |
|            | BV     | 76           | 1.50    |
|            | C      | 78           | 1.40    |
| 10         | A0     | 80           | 1.25    |
|            | BVW    | 84           | 1.10    |
|            | CW     | 92           | 0.80    |
| 11         | A0     | 94           | 0.70    |
|            | BTW    | 97           | 0.60    |
| 12         | HAVE   | 104          | 0.50    |
|            | BTW    | 105          | 0.40    |
|            | C      | 115          | 0.20    |
|            | C1     | 122          | 0.10    |
We note that carbon values recorded in soils that were sampled are close to those of a general nature were recorded in the European Union. Laboratory tests and their modeling shows that Romanian soils are part of European stimulate the agriculture desire to become a factor of stability in world climate. These results encourages us improve the software that transform farmers efforts to sequester carbon in cash. The development money will boost agriculture responsible and respectful with the environment (Table 1, Figure 4, Table 2, Figure 5).

5. Calculating carbon flux in soil
Calculating the carbon content in different situations once the program follows a formula CESAR (Carbon Emission and Sequestration by Agricultural Land Use) [7], [8].

Flow of year t-1 to t in soils in arable and grassland is:

\[ FC = c \ast h_c \ast (Y_{t-1}/H - Y_{t-1}) - r_a \ast C_{t-1} \]

Meadows for grazing (recycling C through animal droppings)

\[ FC = c \ast [h_e \ast (Y_{t-1}/H - Y_{t-1}) + h_f \ast f \ast Y_{t-1}] - r_a \ast C_{t-1} \]

Of organic material in soil: MOS (humus) of organic material > 1 year

\[ FC = c \ast Y_{t-1} \ast H \ast (1 - r_a) \]

Parameters can be found in the literature:

- \( c = 0.58 \) tC t⁻¹
- \( r = 0.029 \) a⁻¹
- \( h_e = 0.44 \)
- \( f = 0.25 \)
Table 3. Value for hc parameter

| Nr.Crt | Crop                  | Value |
|--------|-----------------------|-------|
| 1      | herbaceous crops      | 0.33  |
| 2      | Grain                 | 0.31  |
| 3      | Potatoes              | 0.22  |
| 4      | Sugar beet            | 0.21  |
| 5      | hemp, sunflower, etc. | 0.33  |

Table 4. Value for H parameter

| Nr.Crt | Crop                  | Value |
|--------|-----------------------|-------|
| 1      | herbaceous crops      | 0.45  |
| 2      | cereals harvested     | 0.67  |
| 3      | free cereal straw     | 0.46  |
| 4      | potatoes and sugar beet| 0.69  |
| 5      | for hemp              | 0.42  |
| 6      | flower sun            | 0.92  |

Table 5. Value for Yt-1 parameter

| Nr.Crt | Crop                  | Value       | Country                                |
|--------|-----------------------|-------------|----------------------------------------|
| 1      | herbaceous plants     | 11 a⁻¹ tm.s ha⁻¹ | Belgium, Netherland, Germany and Romania |
|        |                       | 9.7 a⁻¹ tm.s ha⁻¹ | France                                |
| 2      | grain + straw         | 12 a⁻¹ tm.s ha⁻¹ | Belgium, Netherland                    |
|        |                       | 10 a⁻¹ tm.s ha⁻¹ | Germany, France                        |
|        |                       | 9 a⁻¹ tm.s ha⁻¹ | Romania                                |

Table 6. Net carbon flux results, calculated with specific formulas

| Nr.Crt | Crop                  | Value       |
|--------|-----------------------|-------------|
| 1      | Grassland             | 0.52 t C ha⁻¹y⁻¹ |
| 2      | arable land           | -0.84 t C ha⁻¹y⁻¹ |
| 3      | conversion of arable land to grassland | 1.44 t C ha⁻¹y⁻¹ |
| 4      | application of sludge (10 tons ha⁻¹) | 1.50 t C ha⁻¹y⁻¹ |
| 5      | works fewer           | 0.25 t C ha⁻¹y⁻¹ |
| 6      | straws leaving the soil after harvest crops | 0.15 t C ha⁻¹y⁻¹ |
| 7      | average temperature ± 1 ° | -0.05 t C ha⁻¹y⁻¹ |
| 8      | CO2 + 0.2%            | 0.01 C ha⁻¹y⁻¹ |

6. Software to monitor soil carbon sequestration

The software has a connection interface, allowing the user or administrator with specific credentials and each having its operating rights program (Figure 6).

The application has a database that allows to add all information on existing carbon deposits in the ground and to monitor the flow of carbon annually (Figure 7). They are placed on the data where they can be identify. Then you can upload data on each field he owns farmer and type of crop (cereals, potatoes, fodder plants, etc.) on the field that has a certain type of soil (loam, sandy, loamy, etc.) (Table 6).
Data for the storage of carbon deposit on existing information comes from laboratory tests on the samples taken from the ground [6] (Figure 8).
Regarding the annual flow of carbon from the soil data are obtained as follows: after applying the above formula, based on field verification of declarations provided by the farmer and the supporting documents (Figure 9). Information provided by the farmer shall be supported by certificates of origin for seed culture existing in the plot but also for agricultural work performed or any other intervention in field.

After obtaining these data the program calculates the number of green certificates (Figure 10) incumbent on every farmer in the agricultural year in question. This calculation complies with environmental law in force and can be quickly adapted to any change in the...
law. By law the application can convert these green certificates in cash. Money can automatically turn farmers accounts. The software is designed so as to be consistent with the Agency for Payments and Intervention in Agriculture at the European level.

![GreenCertificates](image)

**Figure 10.** Database number of allowances issued each farmer

He can share data between these databases to optimize human and material costs and resources involved in this. The technology used is Microsoft Visual Studio programming environment with programming language C# [9], [10], [11] and Microsoft SQL Server database [12]. The program can run on any PC or smart device equipped with Windows operating system (Windows XP, Vista, 7, 8, 10). We are considering extending it on Apple and Android platforms.

7. Conclusion
We approached transdisciplinary global environmental problem that can be solved through sustainable development agriculture. This agriculture which uses innovative ideas can become sustainable in the long term in terms of environmental protection. Agriculture and informatics especially mechatronics can provide sustainable solutions through knowledge and can transform a field emitter and environmentally reckless in one profitable and friend of nature. Biological nutrition can be so healthy. By integrating new technologies we can protect people from the economic or social crises and even self-destruction.

We will refine these ideas by integrating new technologies in agriculture on a large scale. The next stage involves extending the software used on most computer platforms, intuitive menu improvement, integration of domain specific automation equipment and not least harvesting energy potential. We want to achieve and how to plan for the long-term carbon sequestration to support farmers. We will thus achieve an even better their outreach through planning and coordinating. We hope to offer through our approach to optimize predictability and rational use of natural resources as a source of food and as a carbon sequestration reservoir.
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