

# Pedogenic processes of carbonate rocks in the tropical region as a key for sustainable soil management

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**Submission date:** 23-Feb-2021 05:33AM (UTC+0700)

**Submission ID:** 1515608928

**File name:** Ahmad\_2021\_IOP\_Conf.\_Ser.\_Earth\_Environ.\_Sci.\_648\_012012.pdf (750.94K)

**Word count:** 2289

**Character count:** 12141

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To cite this article: A Ahmad *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **648** 012012

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## Pedogenic processes of carbonate rocks in the tropical region as a key for sustainable soil management

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**Abstract.** Efforts to maintain the available nutrients on the soil are very important in management. This research aims to study the pedogenic processes of carbonate rocks in the tropics as a key for sustainable soil management. Five carbonate rock samples and 23 soil samples from 8 soil profiles in areas cultivated as paddy fields were analyzed. Increasing soil depth means decreasing soil organic matter content from 5% to 2%, soil pH ranges from 5.72 to 6.81, but calcium content is only in the low to moderate range (3-8%). The pedogenic process of carbonate rock shows an increase in oxide minerals and nodules both on the part of the soil used in tillage and no-tillage. Most of the calcite minerals that exist in the soil have turned into micrite (small size of calcite minerals), oxide and clay mineral which shows the weathering of calcite minerals which resulting in the release of CO<sub>2</sub> because it is not bound in the clay mineral composition and oxide minerals. The release of CO<sub>2</sub> gas into the air must be inhibited by the addition of organic matter through the incorporation of crop residues to the soil, so that sustainable land use can be maintained and the greenhouse gas effect can be inhibited.

### 1. Introduction

Carbonate rocks composed of minerals calcite, dolomite, aragonite, and siderite, etc. [1]. These provide nutrient supply for the soil and plants. The characteristics of carbonate rocks that are easily dissolved by rainwater cause the rate of soil development in the tropics faster than other regions [2]. This is also directly decreasing soil fertility in the carbonate rock-based areas. The amount and intensity of rainfall give many effects in the pedogenic processes, likewise with the waterlogged on soil for paddy fields [3,4]. Studies related to soil pedogenic processes in tropical regions that have been used for cultivated need to be carried out to ensure the sustainability of land use.

The pedogenic processes in the soil provide information regarding soil minerals weathering, oxide minerals, and organic matter to the soil micromorphology that is formed [5–7]. So that the process for maintaining the available nutrients on the soil are very important in management and answer the best management that can be given. The research aims to study the pedogenic processes of carbonate rocks in the tropics as a key for sustainable soil management.



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## 2. Materials and methods

The study site was located in Bantimurung District of Maros Regency in South Sulawesi Province (figure 1), with coordinate's location: 119°30'0" E to 120°6'0" E and 4°42'0" S to 5°12'0" S. There are five carbonate rock samples, and 23 soil samples from 8 soil profiles in cultivated paddy fields were analyzed from soil. The soil took at two layers, namely; tillage layer (0-20cm) and no-tillage layer (>20cm) on each profile.

Carbonates rock was prepared using thin section method and analyzed with Kerr and Stoop procedures [8,9]. Soil pedogenic features analysis was prepared using Benyarku and Stoop method [10] and analyzed in a polarizing microscope according to Bullock, Stoop, and Fitz Patrick Procedures [9,11,12]. Soil was analyzed for pH, texture, organic matter, and calcium cations with BPT procedures [13].

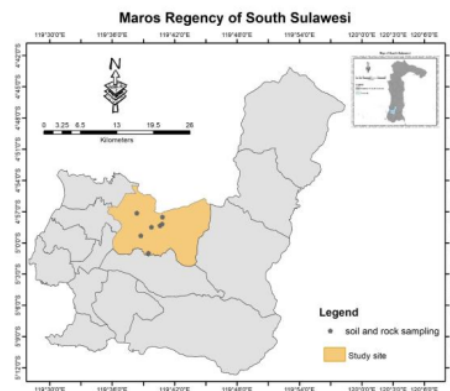


Figure 1. Study site location.

## 3. Results and discussion

### 3.1 Rainfall

Based on Oldeman classification and 10 years climatic data [14], the study area was classified having climatic type C-2 with the number of wet and dry months reaching 6 and 3 months respectively (figure 2).

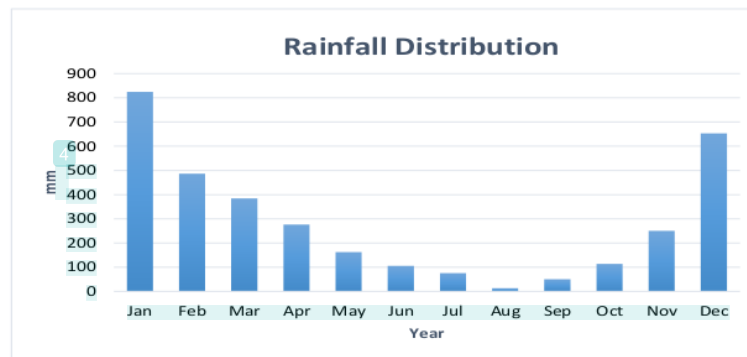
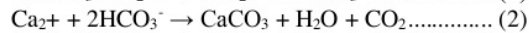
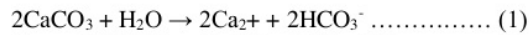


Figure 2. Rainfall Distribution in Maros Regency during 2010-2019.

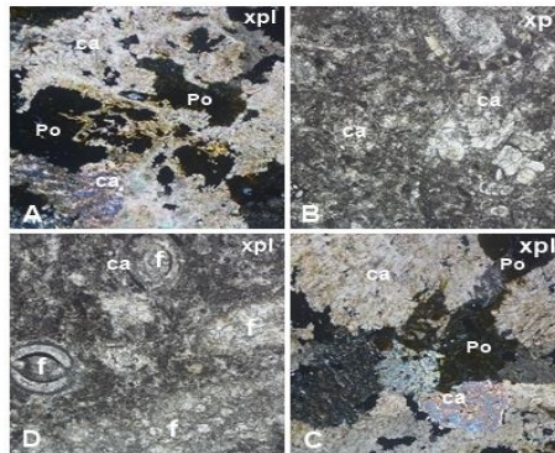
The C-2 climatic type only suitable to plant paddy once/year and cereal crops for the following season. However, at the study site, paddy is planted twice at the beginning and end of the year. This caused high intensive tillage of soil and inundation will increase redoximorphic features [15].

### 3.2 Carbonate rock characteristic

The parent rock at the study site belonged to the carbonate sedimentary rock of the Tonasa (Tent) Formation which age is Eocene to Miocene [16]. Limestone is a type of sedimentary rock that contains lots of calcium carbonate, with a mineral composition of Calcite, Dolomite, Aragonite, and so on [1]. The nature of the carbonate parent material generally forms soil that tends to be clayey, and has red colour [3]. Limestone found in the study site contain Foraminifera fossils as an indicator of the inner shelf environment  $\pm 50$  meters above sea level [17] (figure 3). The difference in environmental conditions of alkaline formation and slightly acidic rainwater content makes the dissolving process tends to increase and releases  $\text{CO}_2$  gas during recrystallization of calcite minerals [18] in the parent rock (figure 3).



The parent rock in the study site was affected by intrusion from igneous porphyry basalt rock, which had an effect on recrystallization of calcite minerals in the carbonate rock bodies and soil development.



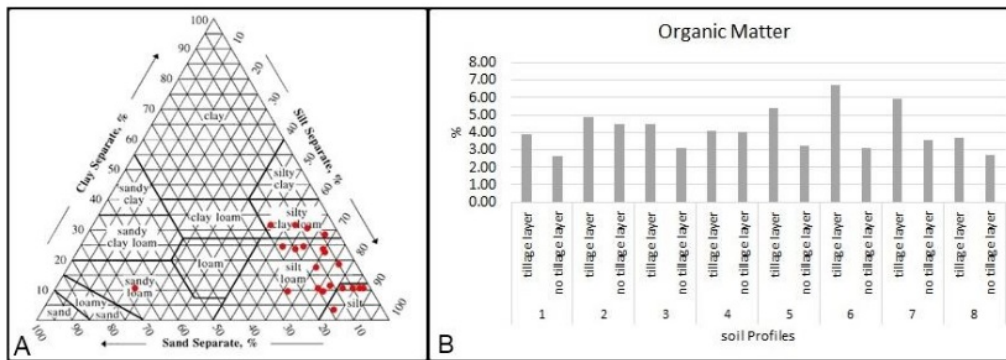
**Figure 3.** Recrystallization of carbonate rock in the pore of rock (A-C) indicated  $\text{CO}_2$  release from soil, and D. showed several fossils in the parent rock (size  $100\mu\text{m}$ ).

### 3.3 Pedogenic processes

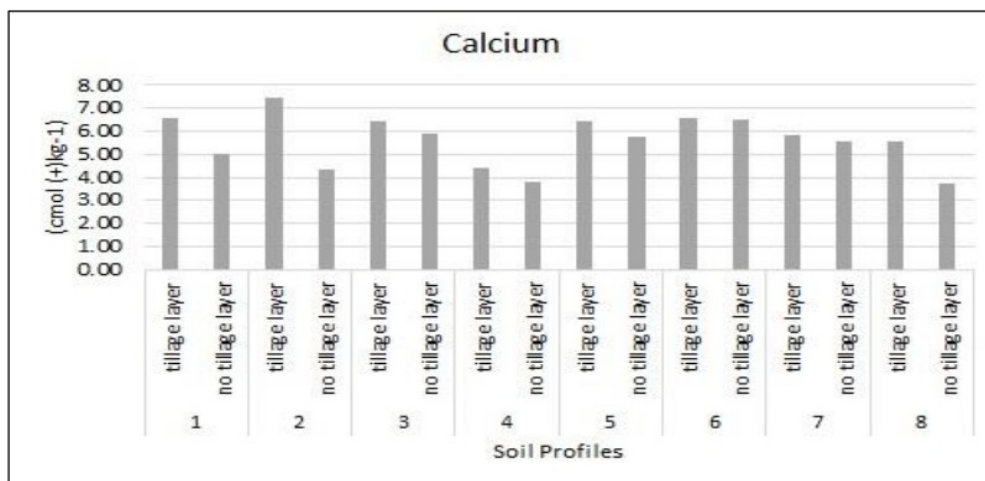
The soil has the dominant characteristic such as texture of silt loam (figure 4) as a sign of moderate developing soil with clay content  $<40\%$ . Soil pH ranges from 6-6.81, soil organic matter in the tillage layer is higher than no-tillage layer, but most of the organic matter in the soils looks decreasing (figure 4) due to the lack of action of returning organic matter to the soil, the farmers prefer to sell the remaining harvest as animal feed. The dominant soil calcium content is in the low category [13] which indicates an increase of the eluviation process in the soil, but is still in a sufficient range for lowland rice plants (figure 5).

Recognizing pedogenic processes indicated the redoximorphic reactions occur in high process due to intensive cultivation. The redoximorphic process is in line with the formation of oxide mineral (figure 6). The soil structure formed an angular blocky in the tillage layer as mark of high cultivation [6]. The silt and clay coating on the tillage layer is hypocoating, with nodules in the aggregate form, c/f ratio 2/3, and enaulic c/f related distribution. Meanwhile, the no-tillage layer shows the appearance of granostriated and porostriated resulting from the silt-clay eluviation process from the tillage layer (figure 7). The structure formed sub-angular blocky, the dominant silt and clay coatings are hypocoating and quasicoating. Nodules form typic and aggregate, c/f ratio 3/2, and enaulic c/f related distribution.

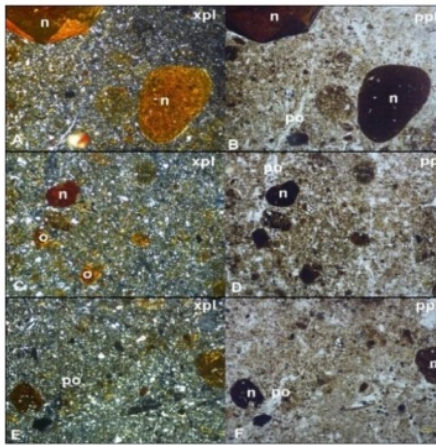
The pedogenic process of carbonate rock shows an increase in oxide minerals and nodules both on the part of the soil used in tillage and no-tillage. This also occurs in another land use from carbonate parent rock [19]. The increasing amount of mineral oxides requires further handling so that they do not become toxic to plants and do not reduce soil fertility [20].



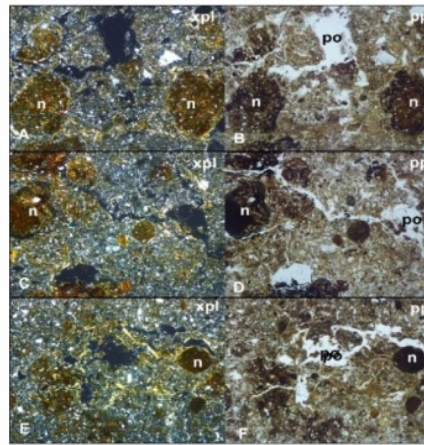
**Figure 4.** Soil texture is dominated by silt loam (A) and soil organic matter in tillage and no tillage layers of eight profiles (B).



**Figure 5.** The concentration of calcium in soil that showed decrease status.



**Figure 6.** Appearance of pedogenic features in the tillage soil with more aggregate nodule form (A-F), angular blocky structure (D and F), and planes void (B, D, F), hypocasting (A and C); n (nodule), o (oxide minerals), po (pore) (size 100 $\mu$ m).



**Figure 7.** Appearance of pedogenic features in the no-tillage soil under the tillage soil with typic and aggregate nodule form (A-F), sub-angular blocky structure (D and F), and chamber void (B, D, F), hypocasting and quasicasting (C and F); n (nodule), po (pore) (size 100 $\mu$ m).

### 3.4 Soil management

Most of the calcite minerals that exist in the soil have turned into micrite (small size of calcite minerals), oxide and clay mineral which shows the weathering of calcite minerals which results in the release of CO<sub>2</sub> because it is not bound in the clay mineral composition and oxide minerals [21,22]. One way to capture CO<sub>2</sub> from the weathering of calcite minerals in the soil by chelation it by adding the organic compost. Verrecchia's [18] results showed the reaction of CO<sub>2</sub> gas in an active oxidation-reduction environment with organic materials to form secondary carbonate minerals. It means that the addition of organic matter through the incorporation of crop residues to the soil will reduce the greenhouse gas effect, so that sustainable land use can be maintained.

### 4. Conclusions

The pedogenic process of carbonate rock shows an increase in oxide minerals and nodules both on the part of the soil used in tillage and no-tillage. Most of the calcite minerals have been altered to micrite (small size of calcite minerals), oxide and clay mineral indicating the weathering of calcite minerals and releasing CO<sub>2</sub> because it is not bound in the clay mineral composition and oxide minerals. The release of CO<sub>2</sub> gas into the atmosphere must be inhibited by the addition of organic matter through the incorporation of crop residues to the soil, so that sustainable land use can be maintained and the greenhouse gas effect can be inhibited.

### Acknowledgments

Thanks to Institute for research and Community Service of Universitas Hasanuddin for the funding provided.

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