A study of the relationship between the oxidation-reduction layer and the denitrification activity in paddy soil

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INTRODUCTION

In the agricultural sector, excessive fertilization causes a variety of nitrogen pollution problem. The nitrogen removal of paddy fields/wetlands is a nitrogen pollution countermeasure. Paddy fields and wetlands contribute to nitrogen removal. Denitrification is a process of nitrate reduction that may ultimately produce molecular nitrogen (N_2). Kuroda et al. (1976) found that both reductive and oxidative conditions are present in a thin soil layer of paddy field and the thickness of the oxidized layer will influenced nitrification. When dissolved oxygen (DO) is consumed in the presence of easily decomposable organic matter in the soil, then the soil becomes a reduced state (Sadao E, 2012). On the other hand, the DO concentration in flooding water has diurnal variation and the oxidative condition in the daytime becomes oversaturated (Kasubuchi, 2010). It must affect the denitrification of the paddy field soil (**Figure 1**).

In this research, characteristics of seasonal changes of aerobic layer thickness in paddy field soil had been studied. A DO concentration sensor was used to measure the thickness. We also investigated the thickness influence on a denitrification. We measured denitrification activity using the acetylene blocking technique (Toda and Hidaka, 1996).

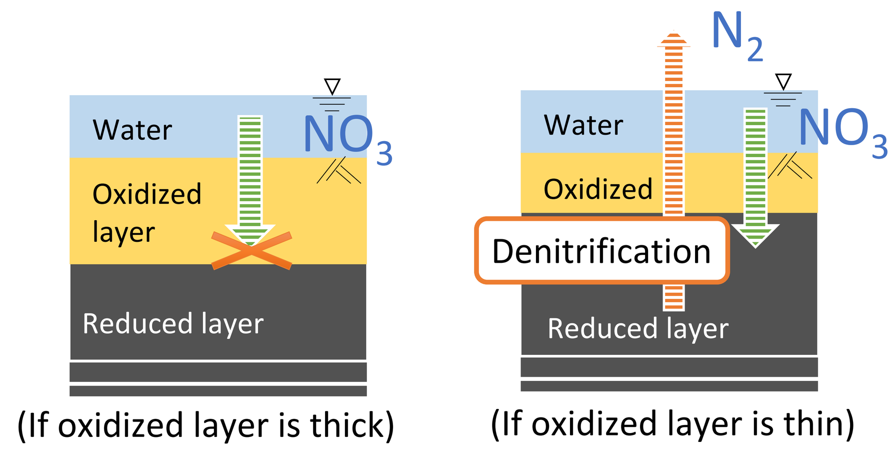

Figure 1. Image for denitrification in flooding soil layer. Denitrification must be low when an oxidized layer is thick and high when the layer is thin.

Method

Site description

This research was under taken at the O area in Ami town, Ibaraki prefecture in Japan (**Figure 2**). It has fields and forests on a plateau paddy fields in lowlands.

The experiment dates were on July 24, August 19, September 18 and October 30, 2014, and June 4, July 9, August 27, October 15, 2015, respectively. Measurements were taken at about AM 9:00 o'clock.

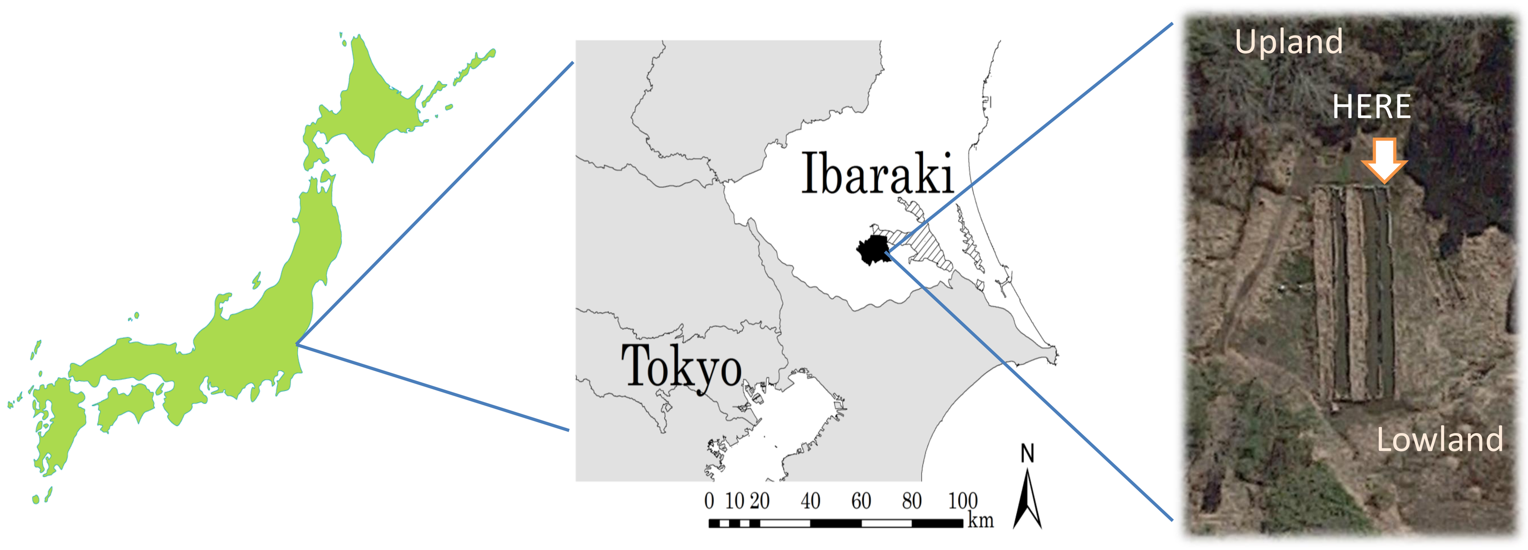

Figure 2. The location of study are. This site has been maintained as an experimental paddy field for studies of the nitrogen removal for more than 20 years. The research plot is a non-vegetation plot with all year irrigation. The plot size is 25 m * 1.4 m. Depth of flooding is 5~ 6 cm. There is no subsurface infiltration in this area.

Soil sampling

Soil samples were collected 3 points by undisturbed sample. Soil temperatures were measured just above soil surface. Then each sample was measured the DO concentration in soil samples by a DO concentration sensor (Unisense comp.) (**Figure 3**).

Because DO concentration measurement values is not capable of indicating a perfect redox state, instead we use "**aerobic layers**" and "**anaerobic layers**". The DO concentration border of an aerobic layer and anaerobic layer is 0 mg L^{-1}. Based on the DO concentration results, oxidized layers and reduction layers were collected for analyzed their denitrification activities.

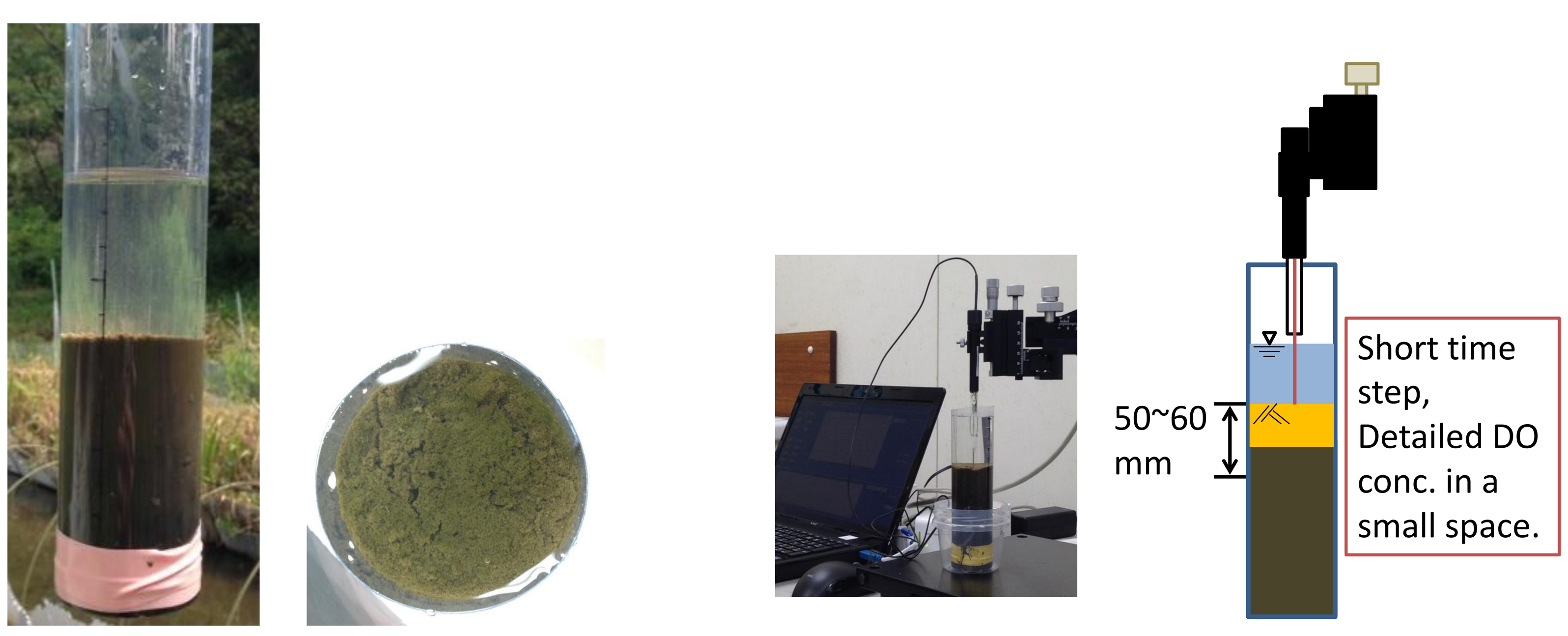

Figure 3. DO concentration measuring. (a) A soil core sample for the measuring. Three samples were collected at middle point of the paddy filed. (b) A DO concentration measuring device and a setting at measurement. The DO concentration was measured from a soil surface to a depth of 50,60 mm. The step sizes we moved the microsensor was 200 µm. DO concentration is curvilinear in soil with increasing depth. In order to prevent contamination during soil sampling, the soil of aerobic layers where the DO concentration was above 1 mg L^{-1} was sampled, along with anaerobic layers of less than 0 mg L^{-1} in this study.

Results and discussion

DO concentrations of soil

The DO concentration in soil layers had high amount at surface and dropped sharply as it goes downward (**Figure 4**). In this study, we called "an aerobic layer thickness" depths to 0 mg L^{-1}.

Average values of aerobic layer thicknesses were 20.7 mm, 16.0 mm, 43.3 mm, 30.1 mm, 51.3 mm, 64.4 mm, 84.1 mm and 30.5 mm to the survey date days, respectively (**Figure 5**). The DO concentrations changed in range of 10 ~1.5 mm in soil layer and became deepest between August and September. A positive correlation is observed between aerobic layer thicknesses and soil surface temperatures in the range of 12 ~ 24 ° C.

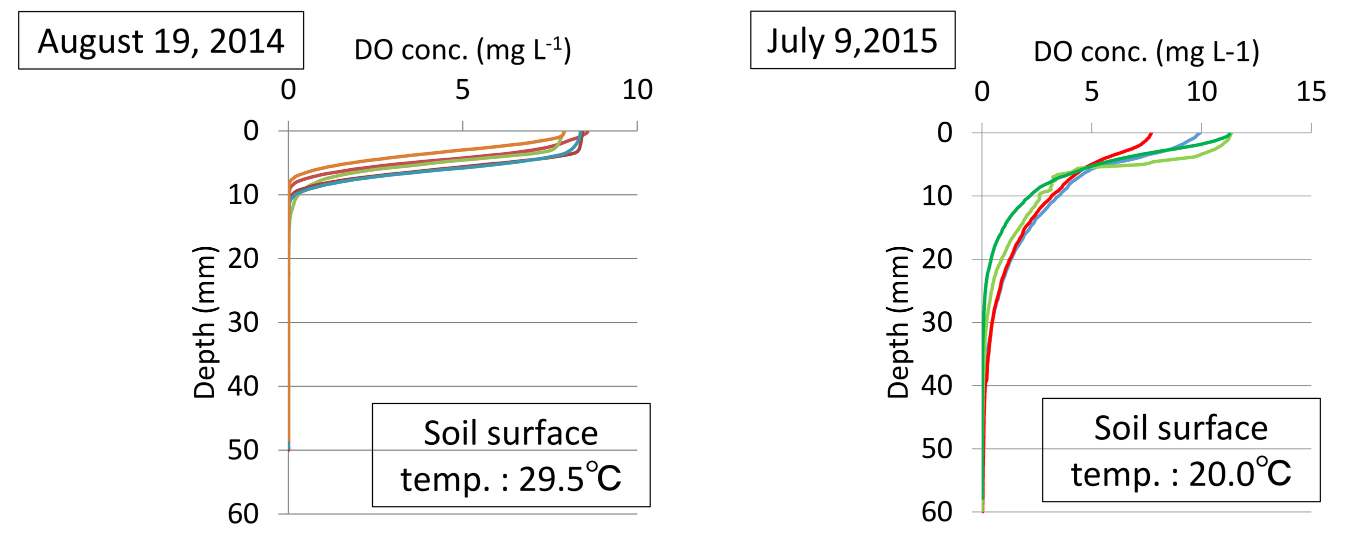

Figure 4. Examples of the DO conc. measurement results.

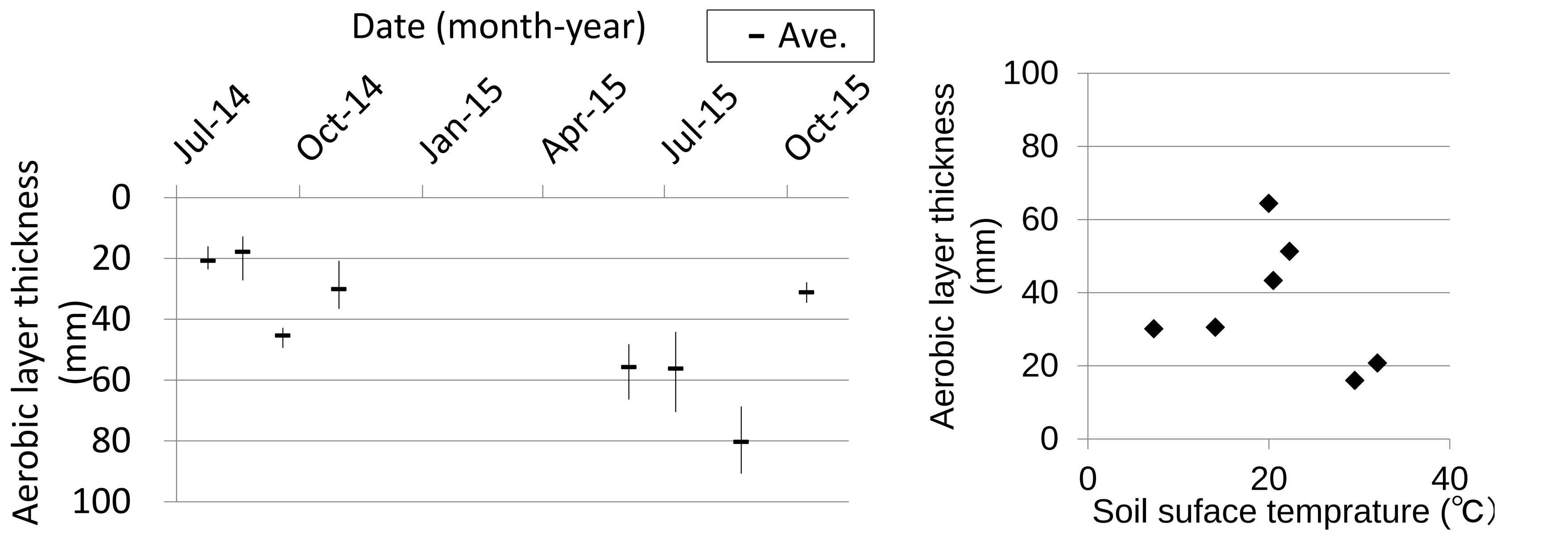

Figure 5. Results of aerobic layer thickness. (a) Aerobic layer thickness on each survey day. "-" shows average values of aerobic layer thicknesses. (b) A correlation diagram of soil surface temperature and aerobic layer thicknesses.

Denitrification activity

The highest denitrification activity was 4.0 µgN g-wet^{-1} d^{-1} at September 2014, and the smallest was 0.1 µgN g-wet^{-1} d^{-1} at October 2014 in aerobic layers. Also, in anaerobic layers, they were 27.2 µgN g-wet^{-1} d^{-1} at July 2014 and 11.5 µgN g-wet^{-1} d^{-1} at October 2014, respectively.

The denitrification activity of aerobic layers rose from August to September and dropped in October. Denitrification activity in anaerobic layers was lower from August to October and higher than denitrification activity of aerobic layers. A negative correlation is observed between the denitrification activities of anaerobic layers and aerobic layer thicknesses (**Figure 6**).

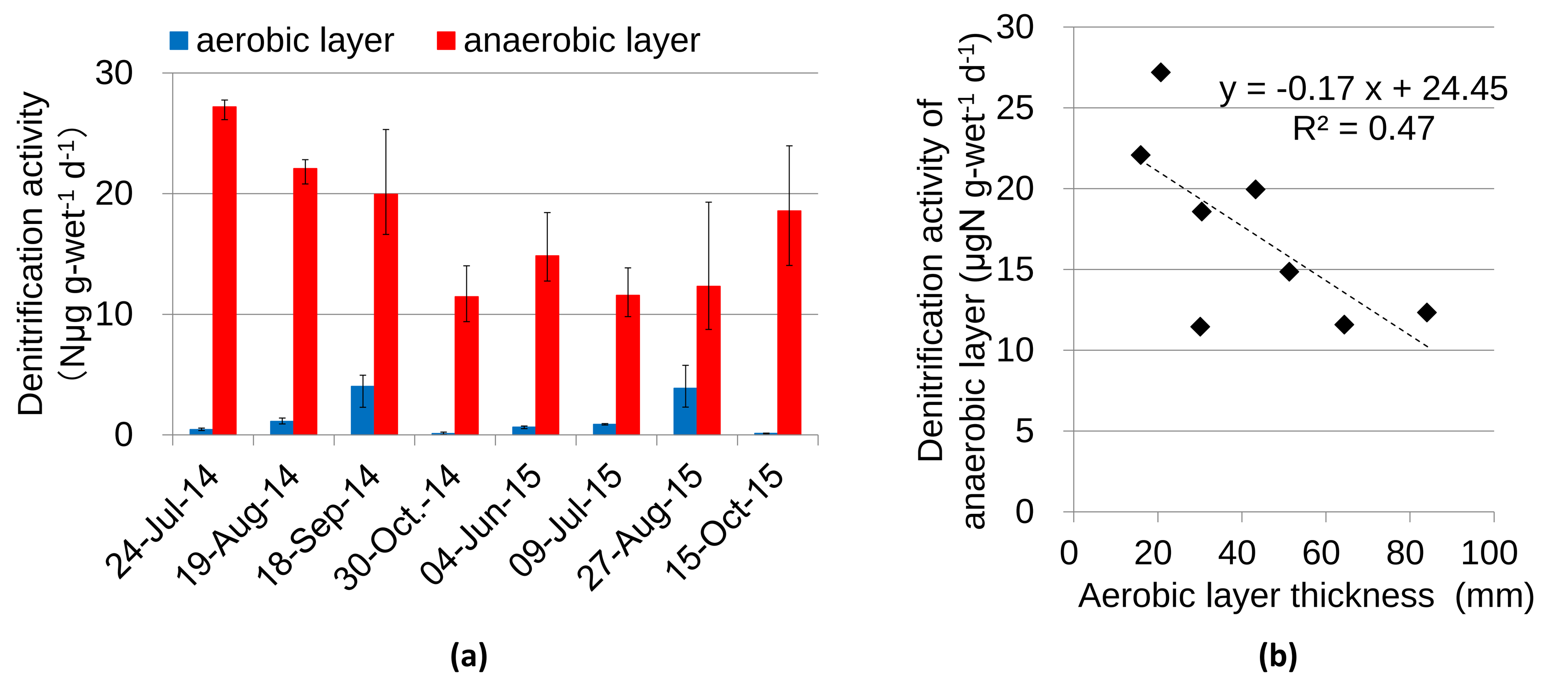

Figure 6. Results of denitrification activity. (a) The denitrification activities of aerobic and anaerobic layers on each survey day. (b) A correlation diagram of anaerobic layer denitrification activities and aerobic layer thickness.

Conclusion

In this study, characteristics of seasonal changes of aerobic and anaerobic layers in paddy field soil had been studied. As a result, research has shown as follows.

1) DO concentrations in paddy field soil have a seasonal change and changed in a thin layer.
2) A positive correlation is observed between aerobic layer thicknesses and soil surface temperatures in the range of 12 ~ 24 ° C.
3) Denitrification in paddy fields is dependent on anaerobic layer.

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