Geoenvironmental Approach to Restoration of Agricultural Land Damaged by Tsunami

Approche géo-environnementale de la restauration de terres agricoles endommagées par Tsunami

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ABSTRACT: In this study a geo-environmental approach was used for the restoration of the farmed land which was damaged by salinity, due to tsunami water water in the pacific coast of Tohoku region in Japan. The mega earth quake that hit on 11th March, 2011 has triggered a Tsunami in the coastal areas of Tohoku region. The huge water severely affected various environmental and geo-environmental parameters in that area. Soil salinity in the agricultural land has become a great concern for the after disaster geo-environmental restoration. Various approaches are being tried to get rid of the salinity problem of the agricultural land. In this study, major chemical properties (pH, electrical conductivity) of soil in Rikuzentakata city (one of the most affected areas due to tsunami) were measured in the field test during May and June, 2011. An innovative approach by using compost containing Halo bacteria/salt tolerance bacteria in this area was tested to restore the saline soil. This method can be useful for reducing the excessive salts from the soil. The compost can also provide necessary nutrients to the soil and plant.

RÉSUMÉ : Dans cette étude une approche géo-environnementale a été appliquée à la restauration de terres cultivées qui ont été endommagées par l'eau saline amenée par un tsunami dans la région côtière de Tohoku au Japon. Le méga tremblement de terre qui a frappé le 11 mars 2011 a déclenché un tsunami dans cette région. Cette énorme quantité d'eau de mer a affecté fortement les caractéristiques environnementales et géo-environnementales de la zone. La salinité de la terre agricole notamment est devenue une préoccupation majeure. Plusieurs approches sont expérimentées afin de se débarrasser du problème de la salinité de la terre agricole. Dans cette étude, les propriétés chimiques majeures du sol (pH, conductivité electrique) dans la ville de Rikuzentakata (une des régions les plus affectées par le tsunami) ont été mesurées in situ durant les mois de mai et juin 2011. Une approche novatrice a été mise en œuvre pour restaurer le sol salin ; elle utilise un compost qui contient des bactéries de type archées halophiles. Les bactéries de ce type peuvent utiliser les sels excédants du sol et par conséquent réduire le taux de salinité. Ce compost peut fournir aussi des éléments nutritifs nécessaires au sol et aux plantes.

KEYWORDS: salt damage, agricultural land, restoration, microorganism

1 INTRODUCTION

A disaster is the tragedy of a natural or man-made hazard (a hazard is a situation, which poses a level of threat to life, health, property, or environment) that negatively affects society or environment. A natural disaster is a consequence when a natural hazard (e.g., volcanic eruption or earthquake) affects humans. Tsunamis and earthquakes are two of the most dangerous, and yet the most common, hazards to affect population centres and economic infrastructures worldwide. Generally, tsunami flooding results from a train of long-period waves that can rapidly travel long distances from where they were generated by deep-ocean earthquakes, submarine landslides, volcanic eruptions, or asteroid impacts (Morton et al. 2007). Due to tsunami, the sea water carries sediments and salt. There have been many studies on recent (Nishimura and Miyaji 1995) and ancient tsunami deposits (Minoura et al. 1996, Bourgeois et al. 1988). These include descriptions of tsunami deposits in coastal lake, estuary, lagoon, bay floor and shelf environments, and even the farmland (Shiki and Yamazaki 1996). The mega earthquake and consequent tsunami caused a great damage to, not only human life and infrastructure, but also the agricultural land and crops in Tohoku region, Japan. The after math of the tsunami has created many problems to environment and geo-environment of the affected areas. Soil pollution with high salinity, which made the farmland unusable for cultivation, is one of the major geo-environmental problems. The objective of this study is to know the extent of change of soil chemical properties due to tsunami and to apply an innovative approach to control the salinity of the agricultural land (Omine 2012).

2 TOHOKU REGION PACIFIC COAST EARTHQUAKE

The great east Japan Earthquake (Higashi Nihon Daishinsai in Japanese) of magnitude 9.0 was an undersea mega thrust earthquake off the coast of Japan that occurred at 14:46:23 JST on Friday, 11 March 2011. The location of the epicentre (38.3220 N, 142.3690 E) of this earthquake was 70 kilometres east of the Oshika Peninsula of Tohoku and the hypocenter at an underwater depth of approximately 32 km. It was the most powerful known earthquake to have hit Japan, and one of the five most powerful earthquakes in the world since modern record-keeping began in 1900. The earthquake triggered extremely destructive tsunami waves of around 40 m in height in Miyako, Iwate and Tohoku, in some cases traveling up to 10 km inland. In addition to loss of life and destruction of infrastructure, the tsunami caused a number of nuclear accidents in the power plant in Fukushima that caused evacuation zones affecting hundreds of thousands of residents. The sea water inundated large areas of agricultural land and turned soil saline.

3 SOIL INVESTIGATION

Field test was conducted in Rikuzentakata city of Iwate prefecture to determine chemical properties of soil. Figure 1 shows the damaged area in Rikuzentakata city. This city was

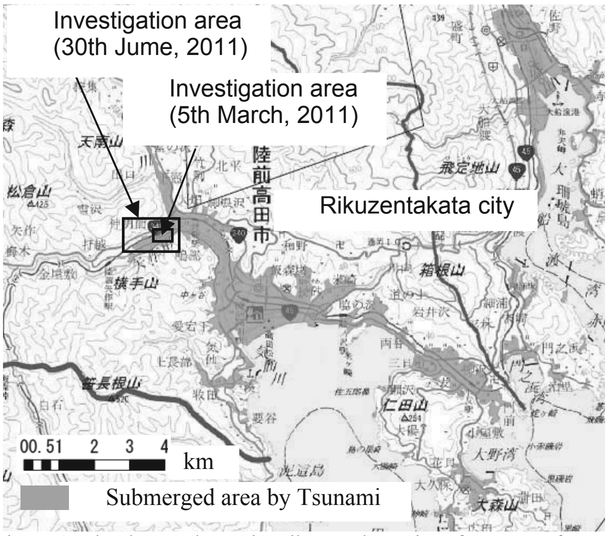

Figure 1. The damaged area in Rikuzentakata city of Iwate Prefecture (The Geospatial Information Authority of Japan, http://www.gsi.go.jp/common/000059844.pdf)

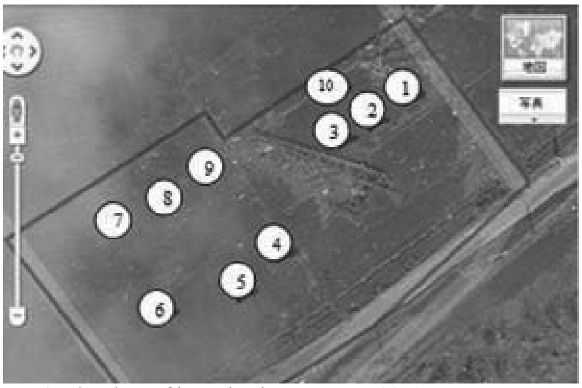

Figure 2. The place of investigation on 5 May 2011

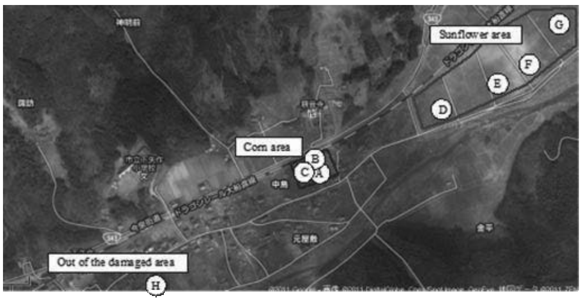

Figure 3. The place of investigation on 30 June 2011

one of the major affected areas by the tsunami on 11 March 2011. Figure 2 shows the place of soil investigation on 5 May 2011 and Fig. 3 shows the place of investigation on 30 June 2011. The sampling area shown in Fig. 1 corresponds to No. F in Fig. 2.

The pH and electric conductivity (EC) of the damaged agricultural land were measured by a digital pH meter (Horiba, D-54SE). The EC of the soil was also measured by using digital an EC meter (Oakton, PCSTEST35). The salinity of the soil was calculated from EC. It is said that normal plants are affected by salt if soil EC exceeds 0.3-0.7 mS/cm. Some parts of the land showed very high EC on 5 May 2011. Table 1 shows the test result of EC and pH. There is the following empirical relationship between Cl (Chlorine) and EC;

Cl content (mg/100g) = EC(mS/cm)×166

The investigation on 30 June 2011 was done in a wide area including the place investigated on 5 March 2011. Table 2 shows the test result of EC and pH. In Fig. 3, No. A~C is corn area, No. D~G is sunflower area and No. H is out of damaged area. The ECs of several soils were low, possibly due to the start of rainy season. Some soils however still showed high EC.

Table 1. Electrical conductivity (EC) and pH of the soils measured on 5 May 2011

(a) EC (mS/cm)

Depth	1	2	3	4	5	6	7	8	9	10
5cm	1.51	0.36	0.39	1.49	1.26	0.47	1.20	1.77	1.01	0.25
10cm	3.04	2.00	1.94	2.93	3.16	1.32	2.77	3.43	1.83	1.15
15cm	2.23	2.43	2.81	4.03	2.21	1.84	0.97	3.46	2.4	2.25

(b) pH

Depth	1	2	3	4	5	6	7	8	9	10
5cm	7.21	8.47	8.06	7.55	7.22	8.39	7.71	7.62	7.19	8.27
10cm	5.75	5.68	6.5	5.78	5.71	6.57	5.98	5.6	6.74	6.52
15cm	6.22	5.48	5.69	5.2	6.13	5.84	7.12	5.64	5.77	5.82

Table 2. Chemical properties of the soils (30th June, 2011)

(a) EC (mS/cm)

Depth	A	B	C	D	E	F	G	H
Surface	0.56	0.11	0.13	0.083	0.09	0.064	0.13	-
5 cm	-	-	-	-	-	-	-	0.032
10 cm	0.97	1.19	0.62	-	0.093	0.15	-	-
15 cm	-	-	-	-	-	-	0.21	-
20 cm	1.83	1.58	1.64	0.21	0.096	0.46		0.026
25 cm	2.15	-	-	-	-	-	-	-
30 cm	-	-	1.65	-	-	-	-	-

(b) pH

Depth	A	B	C	D	E	F	G	H
Surface	7.2	8.1	7.4	8.3	9.0	8.4	8.0	-
5 cm	-	-	-	-	-	-	-	6.9
10 cm	6.6	5.9	6.7	-	9.1	8.4	-	-
15 cm	-	-	-	-	-	-	6.7	-
20 cm	6.1	5.6	5.9	7.0	8.0	7.1	-	6.9
25 cm	6.4	-	-	-	-	-	-	-
30 cm	-	-	5.7	-	-	-	-	-

4 ATTEMPT OF RESTOATION OF AGRIGULTURAL LAND

4.1 *Methods of Restoration*

The aim of soil salinity control is to prevent soil degradation by salinization and to reclaim already degraded soils. Various attempts are now being tested to control salinity of the agricultural land.

The primary method of controlling soil salinity is to permit 10-20% of irrigation water to leach through the soil; the leached water is then drained and discharged through an appropriate drainage system. The salt concentration of the drainage water normally becomes 5 to 10 times higher than that of the

Figure 4. Growing sunflower at the agricultural land

Figure 5. Growing corn at the agricultural land

Figure 6. Building up the compost by mixing rice bran, oil cakes, grinds of fish bones and water

Figure 7. Processing of compost after 3 days

irrigation water. In this process, if export of the salt matches with the import of the salt, then there will be accumulation of salt in the field soil. However, it will take a long time and efforts for such a design of the salinity removal method.

Another method is to establish salt tolerant plants for reducing the salinity of soil biologically. Volunteers for Rikuzentakata (Cheering group of Ganbappeshi Fukuoka) discussed with the authors and proposed to plant sunflower and corn at the saline lands.

They sent a large number of seeds to the local residents and planted sunflower on 9.3 ha and corn on 0.6 ha on 5 June 2011 (Figs. 4 and 5). This method for salinity reduction may not be sufficient for the vast areas.

In this study, an innovative idea was tested for reducing the salt concentration from the agricultural soils. Mr. Usugami who is a researcher of Fukushima produced special compost containing salt tolerant bacteria or halo bacteria for many years (Rural Culture Association Japan , http://www.ruralnet.or.jp/oyaku_image/usu_01.pdf). The volume of the compost can be increased by mixing rice bran, oil cakes, grinds of fish bones and water in a specific ratio. The authors received 2 kg compost from him and increased up to 300 kg. After mixing each material, temperature of the compost was increased to 48˚C for 2 days and turned over for aeration (Figs. 6 and 7). The compost containing the halo bacteria was made ready for application in the tsunami affected large areas of Rikuzentakata for the purpose of reducing salinity of the agricultural land.

For improving the agricultural land damaged by Tsunami, the compost of 10 kg per 1000 m2 and the rice bran of 100 kg per 1000 m2 are needed. The rice bran is nutrition for increasing the halo bacteria/salt tolerance bacteria on site. The rice bran of 30 kg, oil cake of 10 kg, fish lees of 2 kg and water of 35 kg are mixed with the original compost of 2.5 kg using mixer. It was difficult to mix and turn over a large amount of the compost several times, so that the compost was cured in a soil bag with aeration effect as a simple method. Finally, 1 ton of the compost was made and it was brought to Rikuzentakata city together with 4 tons of the rice bran. These materials (compost and rice bran) were disseminated at the agricultural land of 6 ha together with oil-seed rape or rye as green manure crop.

Soil investigation at the site was performed on March 2012. Due to the rail fall and vegetation of sunflower, the salt concentration decreased gradually and the highest EC at the site was 0.25 mS/cm on September 2011. The value of EC decreased furthermore on March 2012. Therefore, it was difficult to distinguish the effect of the compost with halo bacteria/salt tolerance bacteria clearly. It is considered that the compost contains necessary nutrition and the soil is improved.

4.2 *Isolation of Salt Tolerant Bacteria/Halo bacteria*

The sample was collected separately in sterile plastic sheets, and brought to the laboratory for microbiological analysis. For isolation and enumeration of microorganisms, soil sample was serially diluted in sterile distilled water and plated on Luria–Bertani agar (LB g/L:Peptone-10; yeast extract-5; Nacl-10; Agar-15; pH-7.0-7.4) supplemented with 1% sodium chloride (NaCl) level. The plates were incubated at 30oC for 72 hours. Colonies differing in morphological characteristics was isolated in pure form and used for further studies. The screened Halo bacteria was confirmed their growth in specific medium, Mannitol salt agar (g/L: Enzymatic digest of Casein-5; Enzymatic digest of animal tissue-5; Beef extract- 1; D-Mannitol- 10; Sodium chloride- 75; Phenol red- 0.025 g; Agar-15; pH- 7.4) is a selective and differential medium salt tolerance. It contains 7.5% high salt concentration. The salt tolerant bacteria grow in mannitol salt agar and ferment the mannitol, an acidic by product is formed that will cause the phenol red turn to yellow colour.

The salt tolerance was determined in LB agar supplemented with NaCl. The growth was monitored after 72 hours incubation at 30^{o}C. Finally, six types of Halo bacteria were isolated from the compost. At present, Halo bacteria exhibiting 15% salt tolerance was determined in LB agar. Figure 8 shows microscopic view of salt tolerance bacteria isolated from the compost. Figure 9 shows the result of salt tolerance test on the compost. The salt tolerant bacteria exhibited salt tolerance ranged from 16-18 % in LB agar. Optimum growth test of bacterial was not conducted, so that the salt tolerance bacteria are not identified as Halo bacteria herein.

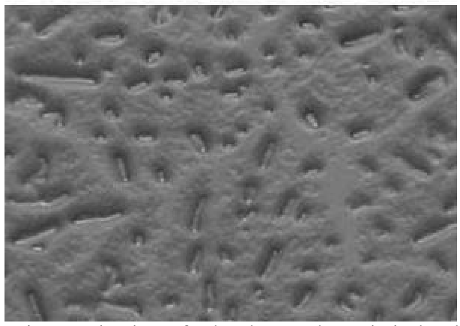

Figure 8. Microscopic view of salt tolerance bacteria isolated from the compost

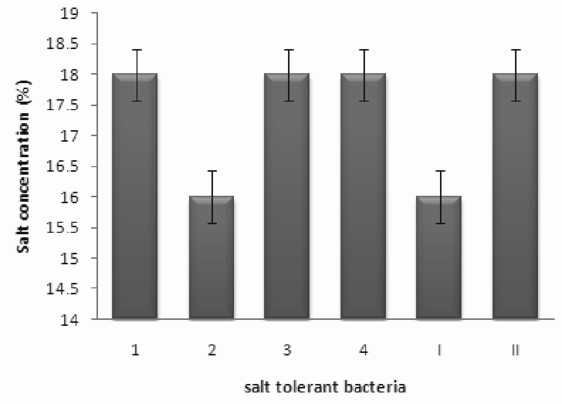

Figure 9. Result of salt tolerance test on the compost

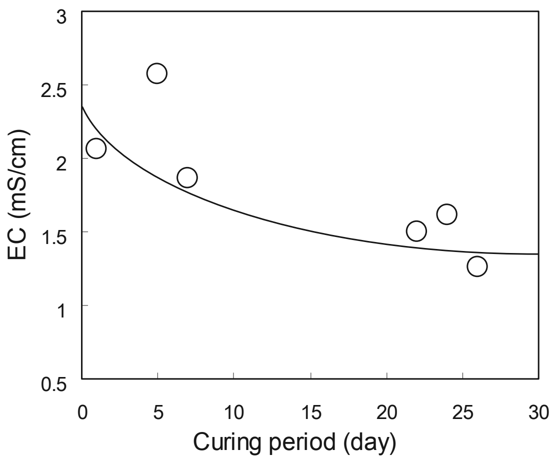

Figure 10. Relationship between electric conductivity and curing period on soil with salt

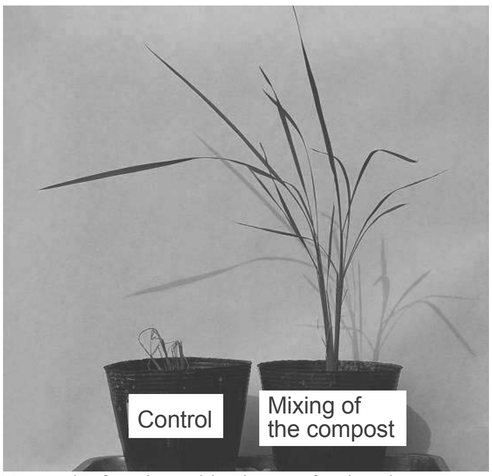

Figure 11. Result of potting cultivation test for rice plants

4.3 *Laboratory tests of Saline Soil*

In order to confirm the effect of the compost with salt tolerance bacteria, laboratory tests of the saline soil were performed.

For making clear the effect, natural salt of 400mg/100g-dry soil was added to a soil sampled from agricultural field at Rikuzentakata city. The compost of 1g and rice bran of 10 g ware mixed with the soil of 330 g. Electric conductivity of the sample were measured continuously as shown in Fig.10. The value of EC decreases with increase in curing period and becomes almost a half after one month.

The farmers in Rikuzentakata city are not able to start a cultivation of rice, because the agricultural land has contained a large size of disaster wastes in the soil still now and tractor cannot work correctly.

It was therefore that the potting cultivation test for rice plants was conducted. Figure 11 shows the test result after one month. In the case of control without the compost, rice plants were died during one week. On the other hand, the plants using the compost have grown steadily.

Thus, the compost with salt tolerance bacteria can reduce the soil salinity and it is also confirmed that the compost is effective for growth of rice plants and restoration of agricultural land.

5 CONCLUSIONS

The mega earthquake and consequent huge tsunami has done a great damage to the entire areas of the pacific regions in Tohoku, Japan. The sea water that overflowed the agricultural lands in the area has created a critical situation for the farmers. The farmers lost not only the crops they were cultivating but also the soil of the agricultural field was seriously damaged by salinity and other pollutants. The pH and EC of the soil have increased and exceeded the safer limit for cultivated crops.

The compost containing salt tolerance bacteria was used at the agricultural land damaged by Tsunami for restoration of the saline soil. However, it was not easy to distinguish the effect of the compost with salt tolerance bacteria clearly due to decrease of salt concentration by rail fall and vegetation. The laboratory tests of chemical properties and potting cultivation were also performed on the saline soil. From the test results, the compost containing salt tolerance bacteria can reduce the excessive salts from the soil and consequently reduced the salinity problem. It was also confirmed that the compost is effective for growth of rice plants. The compost also provided necessary nutrients to the soil and plant.

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