

Landslides in Tea Plantation Fields in Shizuoka, Japan

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ABSTRACT: Shizuoka Prefecture in Japan is famous for the production of quality Japanese green tea. Approximately 45% of Japan's tea is produced in Shizuoka. In this region, tea plants are often grown in hilly terrain. Therefore, due to this topographic setting, as well as other natural characteristics including geotechnical and geological conditions, tea plantation fields are occasionally subject to landslides. This paper investigates the relationship between the tea plantation fields and landslide prone areas in Shizuoka Prefecture. In this study, tea plantation fields are described from the engineering standpoint. Typical mechanisms of landslides that have occurred in the tea plantation fields are also studied. A series of investigations reveal that there are many common points between the tea plantation fields and the landslide prone areas in this region.

Keywords: Landslides, Tea Plantation Fields, Primary Cause, Triggering Cause

1. INTRODUCTION

Drinking green tea has been a part of everyday life for Japanese people for a long time. It is not only part of the Japanese culture, but it also provides health benefits. A number of researchers have revealed various potential positive effects of drinking green tea such as anti-cancer, anti-oxidant, fat burning, prevention of arteriosclerosis, lowering blood pressure and reducing cholesterol.

Shizuoka Prefecture in Japan is famous for the production of quality Japanese green tea. Cultivation of tea plants started this region in 1241 when a monk named Shoichi Kokushi planted green tea seeds which he brought back from China [1]. Cultivation of tea plants became economically important in the 18th century and since then this region leads the tea production in Japan. Today Shizuoka Prefecture produces 40,000 tonnes of tea, which is approximately 45% of Japan's overall tea production, refer Fig. 1.

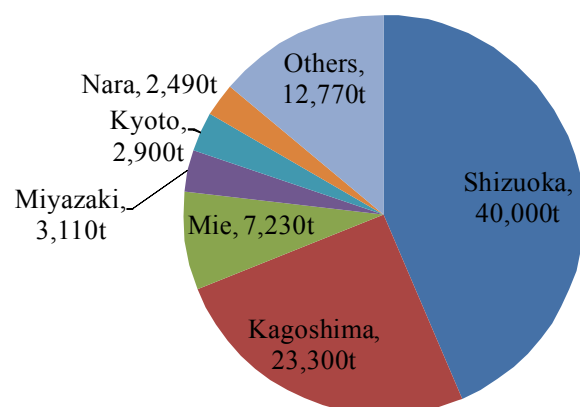


Fig. 1 Amount of Tea Production in Japan (after [2])

The author noticed that tea plants are often grown in hilly terrain and therefore tea plantation fields in Shizuoka are occasionally subject to landslides. In response to this fact,

this paper investigates the relationship between the tea plantation fields and landslide prone areas in Shizuoka Prefecture from the engineering standpoint.

2. TEA PLANTION AND LANDSLIDES

The northern part of Shizuoka Prefecture is surrounded by 3,000 meter high mountains which make up a mountain range called the Southern Alps. Many major rivers in Shizuoka Prefecture originate in this mountain range (e.g. Fuji River, Abe River and Ooi River) or the Central Alps (Tenryu River) and flow downstream to the Pacific Ocean. Due to steep river bed slopes (Fig. 2), these rivers discharge significant volumes of sediment into downstream areas following heavy rainfall events, causing a number of sediment related disasters. At the time of April 2012, there are 24,466 designated sediment related disaster areas in Shizuoka Prefecture [4]. In addition, there are number of geographical areas named after past sediment related disasters such as Hatanagi, Ooyakuzure and Ookuzure in Shizuoka Prefecture.

Major tea plantation areas in Shizuoka Prefecture, shown in Fig. 3, overlap somewhat with sediment related disaster areas. It is known that areas of frequent fog and with a significant temperature difference between day and night produce high quality tea. Hence many tea plantation fields in Shizuoka Prefecture are located on the hilly terrain at the foothills of the mountains. As a result, tea plantation fields in this region are occasionally subject to landslides.

3. MECHANISM OF LANDSLIDES IN TEA PLANTATION FIELDS

3.1 Primary Cause

In Japan, causes of landslides are generally separated into the primary cause and the triggering cause. The primary causes are factors related to topography, geology, hydrogeology etc. and the triggering causes include heavy rainfall, earthquake, earthworks, and others. In this region, it appears that there are many common points such as topography, geology, soil chemistry, hydrogeology and so on between the tea plantation fields and the landslide prone areas. The following sections will discuss typical primary

cause of landslides in tea plantation areas.

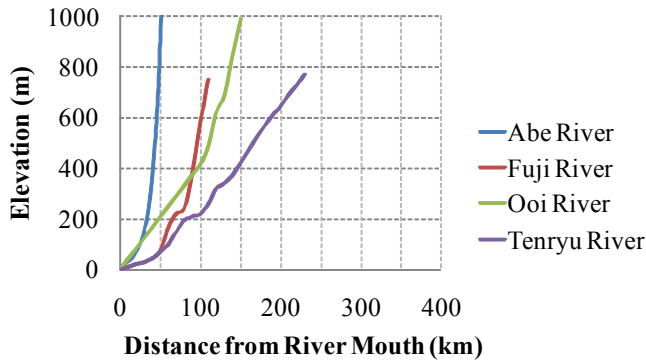


Fig. 2 Relationship between Elevation and Distance from Mouth of Class A Rivers in Shizuoka Prefecture (after [3])

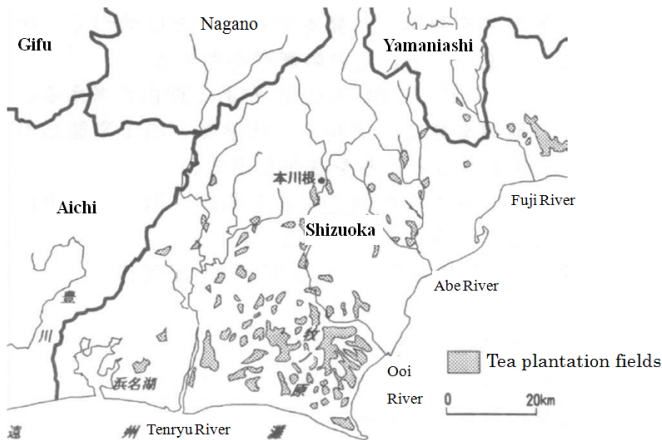


Fig. 3 Major Tea Plantation Fields in Shizuoka Prefecture (after [5])

3.1.1 Topography

In Shizuoka Prefecture, tea trees are often planted on sloping ground (Photo 1). This is because sloping ground can offer various advantages over flat ground, including their good natural drainage system, longer sunshine duration, larger day and night temperature difference and lower risk of cold air stagnation. All these advantages allow production of high quality teas [6] and result in hillsides being the preferred location for tea plantation fields.

Moreover, advantages of planting tea trees on slopes may not be limited to these natural conditions. For instance, choice of productive agricultural products using hilly slopes is very limited. Among these products, tea plantations are considered as one of the most profitable business [7]. In addition, only relatively small sized machines, or no machines, are required in tea plantation fields making it easy to plant tea trees on slopes.

According to [2], 7,377 ha (41% of overall tea plantations in Shizuoka Prefecture) of tea plantations are on ground inclined at less than 8 degrees, 4,081ha (24%) is on ground sloping between 8 and 15 degrees, 5,350 ha (32%) is on slopes steeper than 15 degrees in Shizuoka Prefecture. Since the total area of tea plantations on slopes steeper than 15 degrees is 6,074 ha in Japan, almost 70% of tea plantations on relatively steep slopes are located in Shizuoka Prefecture. This topographic characteristic is considered to be one of the primary reasons that the chance

of landslides in tea plantations in Shizuoka Prefecture is significantly higher than other prefectures in Japan.



Photo 1 Photographs of Typical Tea Plantation Fields on Sloping Ground in Shizuoka Prefecture



Photo 2 Crest of Landslide in Tea Plantation Fields

3.1.2 Geology and Soil Chemistry

High permeability ($> 1 \times 10^{-4}$ cm/sec), high aeration and high water retention are important soil characteristics for growing tea plants. The bedrock of tea plantation fields needs to be deep and the arable soil, free from impermeable layers, must be sufficiently thick. It is also important that the soil mass in the root system does not contain a large portion of fine particles.

The Makinohara Plateau located approximately in the centre of Shizuoka Prefecture is one of the most famous tea production areas in Japan. This area comprises approximately 20 to 30 m thick Ooi River alluvial fan sediments containing Quaternary Pleistocene uncemented gravelly layers and/or mud layers, which is overlying Miocene to Pliocene sedimentary layers. While soils in this region are suitable for growing tea plants due to their weakly acidic and high natural drainage characteristics, there are a number of slope instabilities due to their high erosion susceptibility.

In addition, colluvium slopes on hilly mountains, which are usually considered not suitable for cultivating agricultural products, are often used as tea plantation fields. This is mainly because colluvium, which tends to lose basic minerals and become acidic, is suitable for the growth of tea trees [2].

Tea plants are aluminum-philic and acid resistant. They grow well in the soil in which pH ranges between 4.0 and 5.0. Nitrogen fertilizer is often used in tea plantation fields since the quality of the tea increases with an increase of nitrogen in the soil mass. Because of this, tea plantation fields are often too acidic for other agricultural products. Therefore little beneficial effect from tree roots for reinforcing slope stability is expected in an acidic soil environment. This also contributes to the fact that tea plantation fields are susceptible to the erosion during heavy rainfall events.



Photo 3 Tea Plantation Field in Colluvium Slopes

3.1.3 Past Landslide Sites

Japan has a population of 120 million in an area of about 370,000 km² and has the one of the highest population densities in the world. Therefore the redevelopment of past landslide sites is an important engineering and social topic in Japan. To date, past landslide sites are often used as parks after rectification works in Japan (e.g., Jizukiyama memorial park and Chausuyama park in Nagano Prefecture).

In Shizuoka Prefecture, tea plantation fields are often found in the past landslide sites. The author considers that planting tea trees is a good way of utilising past landslide sites. This is because:

- Profitability of tea plantations per unit cultivable area is generally higher than other agricultural products.
- Machines required in tea plantations (e.g., green tea cut

machine) are smaller in size, lighter in weight and less expensive compared with those required for other agricultural products. Therefore they are transportable to most of the tea plantation fields including difficult access areas on past landslides and hill slopes.

- Soils in the past landslide sites are often acidic due to loss of alkali ion which suite the growth of tea plants.

In the past landslides sites, tea plantations are often located in the depression zone near the landslide crown or the lobate near the landslide toe where the landslides debris are deposited and slopes become relatively gentle.

It should be noted that these past landslide areas may be used without appropriate rectification works and farmers may be using these areas without knowing about past landslide events. Landslides in these areas could be reactivated, even with relatively minor triggering events.



Photo 4 Tea Plantation Field in Past Landslide Site

3.2 Triggering Cause

Triggering causes of landslides are broadly separated into the natural causes and those related to human activity. The natural triggering causes include intense and/or long rainfall events, snowmelts, earthquakes, scouring or erosion of the toe of the slope and so on. Causes related to human activities include excavation, filling, tunneling, ponding of reservoirs, and the like.

3.2.1 Rainfall Events and Groundwater

The tea plants can grow well in areas with an average yearly temperature above 13 degree C, snowfall of not more than 1m and yearly rainfall of more than 1,400 mm [2]. More than 1,000 mm of rainfall is required during the growth period of the tea plants between April and October [9]. Many areas in Shizuoka Prefecture satisfy these requirements due to their warm and moist environment (Fig. 4) and thus tea is the one of the most representative agricultural products in this region.

While rainfall is essential to the growth of tea plants, there are a number of sediment related disasters due to the heavy rainfall events. As shown in Table 1, 86 slope failures occurred due to heavy rainfall events within a relatively short time period.

As described previously, the permeability of the soil in the tea plantation fields needs to be high. Therefore even if the groundwater level is low during the dry season, the rise of

groundwater in tea plantation fields could be significant during or/and after intense rainfall events (Fig. 5).

Under such circumstances, slope failures may occur suddenly without any warnings. Once the slope starts moving, the rate of movement could be also very rapid.

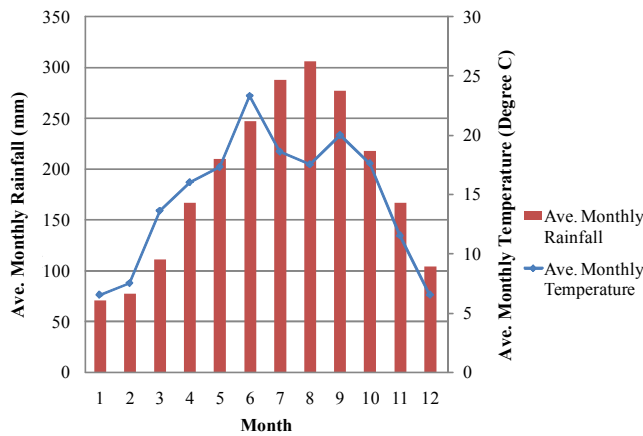


Fig. 4 Rainfall and Temperature of Makinohara City (after [9])

Table 1 Summary of Sediment Related Disasters in Shizuoka Prefecture from 1 Jan. to 3 Oct. 2011 (after [10])

Type	Triggering Cause	
	Earthquake	Heavy Rainfall (incl. Typhoon)
Debris Flow	0	13
Landslides	0	7
Rock falls	7	66
Total	7	86

3.2.2 Human Activities

Shizuoka Prefecture has the largest tea plantations fields in Japan. 2.6% of lands in Shizuoka Prefecture are used as tea plantation fields. Of particular note is that about 25% of Makinohara City's land is used as tea plantation fields [9].

Therefore construction activities are often required to extend into tea plantation fields. As a result, the chance of landslides in tea plantation fields due to these human activities is inevitably high in Shizuoka Prefecture compared with other prefectures.

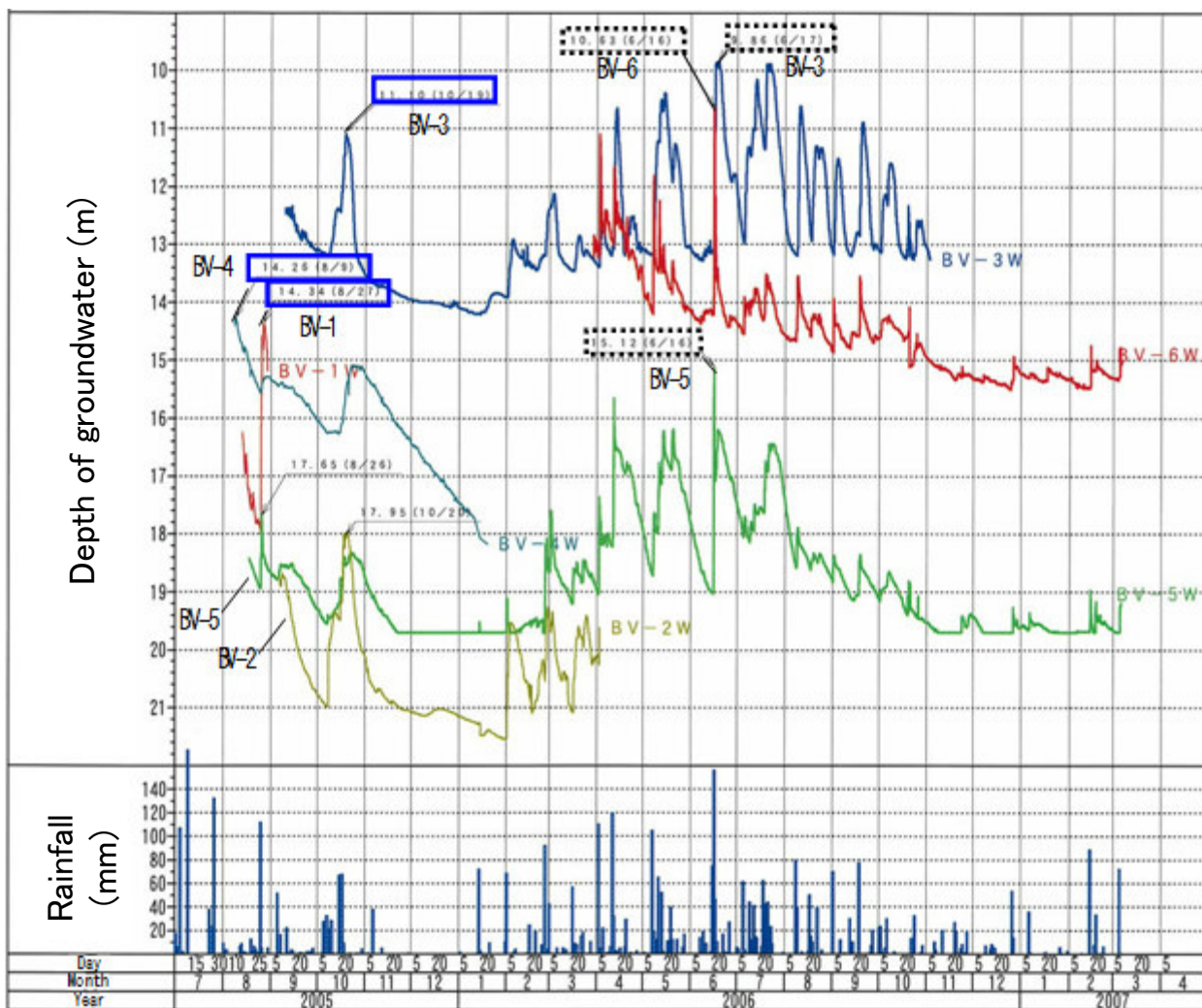


Fig. 5 Significant Rise of Groundwater Level in Tea Plantation Fields due to Rainfall Events



Photo 5 Earthworks Extended Close to Tea Plantation Field



Photo 6 Drainage Well in Tea Plantation Field

4. LANDSLIDE MITIGATION

Shizuoka Prefecture has approximately 41,200 tea farm households, which is the highest numbers in Japan. Tea farming is a very important source of income for them.

Therefore tea farmers are often reluctant to be disturbed by construction activities such as landslide rectification works, particularly during the first tea crop of the season from late April to May. Governmental administration bodies in this region are also fully aware of this issue.

One of the key aspects that needs to be taken into account during the selection of landslide rectification works is to minimise the damage to tea plantation fields. Cutting the upper portions of the slope or filling near the toe of the slope, which affects existing tea plantations fields, is therefore often considered an inappropriate technique by landholders and governmental administration bodies.

Moreover when groundwater control measures (e.g., gravity drains or drainage wells) are adopted for landslide rectification works, it is also important not to drain groundwater completely from the tea plantations fields so that sites remain suitable as tea plantation fields after rectification works.

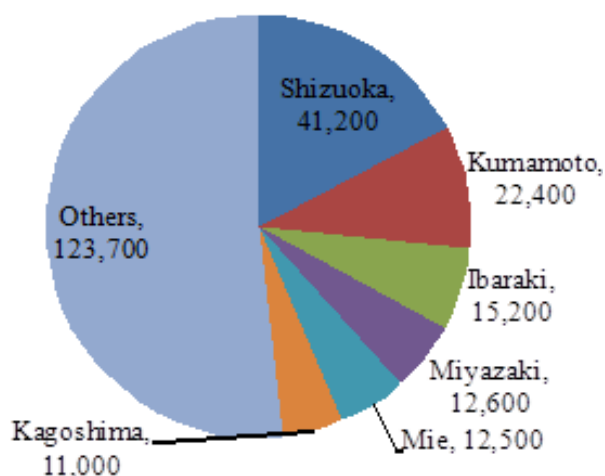


Fig. 6 Number of Tea Farm Households in Japan (after [2])

5. CONCLUSION

In this study, the relationship between the tea plantation fields and landslide prone areas in Shizuoka Prefecture was investigated. A series of investigations reveal that there are many common points between the tea plantation fields and the landslide prone areas in this region. From this study, the following conclusions can be drawn:

- Almost 70% of tea plantation fields on more than 15 degree slopes are located in Shizuoka Prefecture. This topographic characteristic is considered to be one of the primary reasons that the chance of landslides in tea plantations is high in Shizuoka Prefecture.
- Tea plants grow well in soil in which pH ranges between 4.0 and 5.0. Due to this reason as well as meteorological conditions, tea plants can grow in colluvial soils which may be susceptible to the erosion during heavy rainfall events.
- Tea trees are often planted on existing landslide sites. Hence these areas are generally susceptible to reactivation. Landslides in these areas could be reactivated even with relatively minor triggering causes.
- While rainfalls are essential to the growth of tea plants, there are numerous sediment related disasters due to heavy rainfall events.
- Construction activities are often required that extend into tea plantation fields in Shizuoka Prefecture. As a result, the chance of landslides in tea plantation fields due to these human activities is inevitably high in this region.

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7. REFERENCES

- [1] Shizuoka Prefecture, "Shizuoka Green Tea", 2010, http://www.pref.shizuoka.jp/a_foreign/english/tea/index.html
- [2] Rural Cultural Association, "Cha-Daihyakka", vol. 1, Rural Cultural Association, 2008, pp. 269 – 302. (in Japanese)

- [3] Ministry of Land, Infrastructure, Transport and Tourism, “Kadou-Tokusei”, 2007, http://www.mlit.go.jp/river/basic_info/jigyo_keikaku/gaiyou/seibi/ooi_index.html (in Japanese)
- [4] Shizuoka Prefecture, “Number of designated Sediment-related Disaster Areas – Municipality Basis”, 2012, <http://www.pref.shizuoka.jp/kensetsu/ke-350/boushi/zyoukyou.html> (in Japanese)
- [5] Teikoku-Shoin, “How to Chizucho”, 2012, http://www.teikokushoin.co.jp/howto/pdf/index_16/index16/geo_36.pdf (in Japanese)
- [6] Shinseiki Koubou, 2007, <http://www.cha22.jp/daimon/001.html> (in Japanese)
- [7] Chamber of Tea Associations of Shizuoka Prefecture, “Ocha Q&A”, 2012, http://www.wbs.ne.jp/bt/chacha/main/qa_saibai.htm#Q54 (in Japanese)
- [8] Ito En, “Ocha-Hyakka”, 2006, <http://ocha.tv/production/cultivation/> (in Japanese)
- [9] Makinohara City, “Makinohara City Gaikyo”, 2012, http://www.city.makinohara.shizuoka.jp/ftp/05gt04/1_gaikyou.pdf (in Japanese)
- [10] Japan Sabo Association Shizuoka Branch, “Sabo Dayori”, vol. 175, Japan Sabo Association Shizuoka Branch, 2011, pp 2. (in Japanese)

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