LEMBAR HASIL PENILAIAN SEJAWAT SEBIDANG ATAU *PEER REVIEW*
KARYA ILMIAH: di Jurnal Internasional Terindek Scopus Q1 dan WoS

Judul Penelitian : **Geochemical methods for mapping available-Si distribution in soils in West in West Sumatra Indonesia**

Nama Peneliti : **Aflizar , Edi Syafri , Jamaluddin, Husnain, Ahmad Fudholi**

Identitas Penelitian :

a. Jenis Penelitian : Artikel di Jurnal Internasional Terindek Scopus Q1 dan WoS

b. Pembiayaan : Dikti

c. Nomor Surat Perjanjian:

Pelaksanaan Penelitian: 2020

d. Jumlah halaman : 17 halaman

Nama Link : https://doi.org/10.1016/j.geoderma.2020.114833.
http://www.sciencedirect.com/science/article/abs/pii/S001670612032588X.
ttps://www.journals.elsevier.com/geoderma .
https://www.journals.elsevier.com/geoderma/editorial-board

Unit Kerja : Politeknik Pertanian Negeri Payakumbuh

Hasil Penilaian :

Komponen yang dinilai (bobot yang dinilai ditetapkan dalam %)	Nilai Maksimal Penelitian		Nilai Akhir Yang Diperoleh
	Internasional ☑	Nasional ☐	
a. Kelengkapan unsur laporan penelitian (10%)	97 X 10%	. . . X 10%	9,7
b. Ruang lingkup dan kedalaman pembahasan (30%)	97 X 30%	. . . X 30%	29,1
c. Kecukupan dan kemutakhiran data/informasi dan metodologi (30%)	97 X 30%	. . . X 30%	29,1
d. Kelengkapan unsur dan kualitas hasil penelitian (30%)	96 X 30%	. . . X 30%	28,8
Total = (100%)			96,7

Atas dasar tabel di atas, nilai karya tersebut adalah : a. Amat Baik (A), b. Baik (B) c. Cukup (C)

TANJUNG PATI, 12 September 2022

Reviewer: 1

Dr. Aiswarwari Srima Nanggala. S.Si; M.Sc

NIP. 19741204 1999 03 2003

Catatan :

1. Bubuhkan nilai pada kolom yang sesuai dengan karya ilmiahnya Rentangan nilai 50 – 100
2. Konversi nilai angka ke huruf dan sebutannya: 81 – 100 : A (amat baik); 66 – 80 : B (baik); ≤ 65 : C (cukup)

LEMBAR HASIL PENILAIAN SEJAWAT SEBIDANG ATAU *PEER REVIEW*
KARYA ILMIAH: di Jurnal Internasional Terindek Scopus Q1 dan WoS

Judul Penelitian : **Geochemical methods for mapping available-Si distribution in soils in West in West Sumatra Indonesia**
Nama Peneliti : **Aflizar , Edi Syafri , Jamaluddin, Husnain, Ahmad Fudholi**
Identitas Penelitian :
a. Jenis Penelitian : Artikel **di Jurnal Internasional Terindek Scopus Q1 dan WoS**
b. Pembiayaan : Dikti
c. Nomor Surat Perjanjian:
Pelaksanaan Penelitian: 2020
d. Jumlah halaman : 17 halaman
Nama Link : https://doi.org/10.1016/j.geoderma.2020.114833.
http://www.sciencedirect.com/science/article/abs/pii/S001670612032588X.
ttps://www.journals.elsevier.com/geoderma .
https://www.journals.elsevier.com/geoderma/editorial-board
Unit Kerja : Politeknik Pertanian Negeri Payakumbuh
Hasil Penilaian :

Komponen yang dinilai (bobot yang dinilai ditetapkan dalam %)	Nilai Maksimal Penelitian		Nilai Akhir Yang Diperoleh
	Internasional ☑	Nasional ☐	
Kelengkapan unsur isi hasil penelitian (10%)	96.. X 10%	... X 10%	9,6
Ruang lingkup dan kedalaman pembahasan (30%)	96.. X 30%	... X 30%	28,8
Kecukupan dan kemutakhiran data/informasi dan metodologi (30%)	96... X 30%	... X 30%	28,8
Kelengkapan unsur dan kualitas laporan hasil penelitian (30%)	95... X 30%	... X 30%	28,5
Total = (100%)			95,7

TANJUNG PATI, 12 September 2022
Reviewer: 2

NIP. Dr. Eka Susila, SP-MP
NIP. 19730811 1999 03 2002

LEMBAR HASIL PENILAIAN SEJAWAT SEBIDANG ATAU *PEER REVIEW*

KARYA ILMIAH: di Jurnal Internasional Terindek Scopus Q1 dan WoS

Judul Penelitian : **Geochemical methods for mapping available-Si distribution in soils in West in West Sumatra Indonesia**

Nama Peneliti : **Aflizar , Edi Syafri , Jamaluddin, Husnain, Ahmad Fudholi**

Identitas Penelitian :

a. Jenis Penelitian : Artikel di Jurnal Internasional Terindek Scopus Q1 dan WoS

b. Pembiayaan : Dikti

c. Nomor Surat Perjanjian:

Pelaksanaan Penelitian: 2020

d. Jumlah halaman : 17 halaman

Nama Link : https://doi.org/10.1016/j.geoderma.2020.114833.
http://www.sciencedirect.com/science/article/abs/pii/S001670612032588X.
ttps://www.journals.elsevier.com/geoderma .
https://www.journals.elsevier.com/geoderma/editorial-board

Unit Kerja : Politeknik Pertanian Negeri Payakumbuh

Hasil Penilaian :

Komponen yang dinilai (bobot yang dinilai ditetapkan dalam %)	Nilai Maksimal Penelitian		Nilai Akhir Yang Diperoleh
	Internasional ☑	Nasional ☐	
a. Kelengkapan unsur isi hasil penelitian (10%)	(97 + 96) / 2 X 10%	(........... + ...) / 2 X 10%	9,65
b. Ruang lingkup dan kedalaman pembahasan (30%)	(97 + 96) / 2 X 30%	(........... + ...) / 2 X 30%	28,95
c. Kecukupan dan kemutakhiran data/informasi dan metodologi (30%)	(97 + 96) / 2 X 30%	(.......... + ...) / 2 X 30%	28,95
d. Kelengkapan unsur dan kualitas laporan hasil penelitian (30%)	(96 + 95) / 2 X 30%	(........... + ...) / 2 X 30%	28,65
Total = (100%)			96,2

Atas dasar tabel di atas, nilai karya tersebut adalah : a. Amat Baik (A), b. Baik (B) c. Cukup (C)

TANJUNG PATI, 12 September 2022

Reviewer 2,

....

NIP. Dr. Eka Susila, SP. M.P.
[illegible]

Reviewer 1,

Dr. [illegible] S.Si, M.Si

NIP. 1974 12 04 1999 03 2003

Catatan : Bubuhkan nilai pada kolom yang sesuai dengan karya ilmiahnya; Rentangan nilai 50 – 100; Konversi nilai angka ke huruf dan sebutannya: 81 – 100 : A (amat baik); 66 – 80 : B (baik); ≤ 65 : C (cukup)

Geoderma 384 (2021) 114833

Contents lists available at ScienceDirect

Geoderma

journal homepage: www.elsevier.com/locate/geoderma

Geochemical methods for mapping available-Si distribution in soils in West Sumatra, Indonesia

Aflizar[a,*], Edi Syafri[a], Jamaluddin[a], Husnain[b], Ahmad Fudholi[c]

[a] Department of Agricultural Technology, Agricultural Polytechnic, Payakumbuh, West Sumatra 26271, Indonesia
[b] Indonesian Agency for Agricultural Research and Development, Jakarta 12540, Indonesia
[c] Solar Energy Research Institute, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

ARTICLE INFO

Handling Editor: Alberto Agnelli

Keywords:
Spatial analysis
Land-use type
Soil-erosion map
Sawah
Watershed
Physicochemical properties

ABSTRACT

Silicon (Si) is an important element for rice plant, and its availability in soil is an important factor affecting sustainable rice production. Herein, the distribution of available Si and its correlation with land-use type and soil-erosion status were investigated and discussed using the universal soil loss equation (USLE) in the Sumani watershed (SW). This watershed is the main rice-production area in Sumatra, Indonesia. Results showed that the available Si levels in sawah soil were less than 300 mg SiO_2 kg^{-1} on average. Sawah means a leveled and bounded rice field with an inlet and an outlet for irrigation and drainage, respectively. Available Si content in river sediments was also studied and determined to be higher than those in sawah or other land-use types. This finding may indicate that available Si or soil rich in Si was redistributed through soil erosion. Soil-erosion rate was negatively correlated with the concentration of available Si in soils. Land-use types with smaller values of crop factor in USLE calculation and soil with lower pH showed relatively lower available Si in the soils. Overall, our findings indicated that soil erosion and land-use types affected the distribution of available Si in the watershed.

1. Introduction

Silicon (Si) is an important element for rice production (Imaizumi and Yoshida, 1958). However, it is not a concern and has never been applied in sawah in Indonesia. In the field, blast diseases affect local rice varieties, which may be due to the deficiency of available Si, and several studies regarding the Si effect on rice production has been published in Indonesia. Darmawan et al. (2006) reported that about 11%–20% of available Si decreases in sawah soil owing to intensive rice cultivation over the last three decades. In addition, Husnain et al. (2008) reported that in West Java, the supply of Si in lowland sawah through irrigation has decreased because dissolved Si (DSi) is trapped by diatoms (phytoplankton) in dams. However, few studies have focused on the influence of Si availability on rice production and improving Si management.

To mitigate the above problems and thus improve the land-management planning of the watershed, soil erosion must be reduced. To realize this, the present status of soil erosion in relation to land-use pattern in the watershed needs to be evaluated. However, directly determining the soil erosion of the entire watershed is impractical as the necessary measurements are too broad ranging and time consuming. Estimating soil erosion using models is more common and practical. Several types of models for the estimation of soil erosion have been developed, and they include the universal soil-loss equation (Ahmadi et al., 2006; Amore et al., 2004; Moehansyah et al., 2004; Walling et al., 2003; Kusumandari and Mitchell, 1997). In general, no single best model exists for all applications. Thus, the most appropriate model depends on the purpose of the study and the characteristic of the watershed (Shamshad et al., 2008). The application of USLE was evaluated to be sufficient for estimating soil-erosion rates as it can exhibit a relative ranking of soil-loss risk in watersheds when accurate parameter values are used. The USLE has also been used as a conservation-evaluation tool in Indonesia as aforementioned, although few studies have focused on measuring or estimation soil erosion (Aflizar and Masunaga, 2013).

The distribution of silica (silicon dioxide, SiO_2) in soils is influenced by parent material, climate, vegetation, texture, pedogenesis, intensity of weathering (Hallmark and Wilding, 1982), and soil-erosion factor (Aflizar et al., 2018). The SiO_2 source for rice plant was derived from soil, irrigation water, and plant residue such as straw and rice husk if they are incorporated into the soil after harvesting. Soils derived from ash volcanic parent material contain more SiO_2 (Imaizumi & Yoshida,

* Corresponding author.
E-mail addresses: aflizar_melafu@yahoo.com, aflizar@politanipyk.ac.id (Aflizar).

https://doi.org/10.1016/j.geoderma.2020.114833
Received 21 March 2020; Received in revised form 4 November 2020; Accepted 7 November 2020

1958) than do soils derived from alluvium material, particularly those in lowlands. Many rice fields or sawah located in lowlands has parent materials that are mostly river sediment or alluvium, so the original SiO_2 availability is generally low (Aflizar et al., 2019). Rice is a typical Si-accumulator plant that takes up Si from soil solution through an active mechanism (Ma et al., 2001, 2007).

According to Wu et al. (2009), the solubility of Si is influenced by pH and iron (Fe). Soil physical properties (texture, clay percentage, silt and sand) and soil chemical properties (pH, total carbon (TC), total nitrogen (TN), calcium (Ca), magnesium, potassium (K) and sodium (Na)) are used for sustainable land management in agriculture (Hartemink, 1998). Wang et al. (2009) reported that the distribution patterns of TN, total phosphorus (TP) and other nutrients significantly change with changes in land use, and distribution maps can be used to develop sustainable agriculture and improve the environment. Aflizar et al. (2018) reported that the distribution of trace metal cadmium on a watershed is influenced by soil properties including pH, texture, TC, erosion and topographic factors.

The Indonesian government does not believe and does not acknowledge that silica (Si) deficiency has occurred in paddy soils in the country (Husnain et al., 2018; Darmawan et al., 2006). However, we hypothesise that there is an Si deficiency in the soil, especially in the Sumani watershed (SW). Thus, the conditions of rice fields in Indonesia should be evaluated. Soil erosion is considered only as a carrier of adverse effects on the environment because it causes soil degradation and disasters for the environment and agriculture (Aflizar et al., 2010). We hypothesise that soil erosion also has a good effect on the environment because it carries nutrient-rich soil sediments and precipitates them in lowland rice fields.

Many farmers and agricultural practitioners in Indonesia assume that soil Si is not necessary for paddy sawah, so they believe that adding Si in artificial fertiliser is not necessary (Husnain et al., 2018; Darmawan et al., 2006). Moreover, the soil can sufficiently provide natural Si. We hypothesise that Si in the soil is no longer sufficient for paddy sawah and that Si is contributed from irrigation water, river water (Somura et al., 2006) and sediments, which is then naturally distributed to the sawah. However, the content of Si is no longer sufficient; therefore, Si should be added in the form of fertiliser to the sawah soil.

The present study aimed to determine the factors influencing the distribution of available Si in the SW, where volcanic ash and Si fertiliser of irrigation water can be natural sources. We hypothesise that the pH, TC, TN, base cation (Ca, K, Na) and trace metal Fe are factors controlling Si availability in sawah soil. Accordingly, we conducted a study on the distribution of available Si in relation to land-use types and soil-erosion status in the SW, a main rice-production area in West Sumatra, Indonesia. We have already previously observed that severe erosion occurred in the highlands of the watershed because of the land-use change from forest to agricultural field. Accordingly, we expected that these factors may influence available-Si distribution in the watershed. Soil erosion is generally regarded as a type of soil degradation. However, it may contribute to nutrient replenishment in sawah, especially in the lowlands, through the deposition of fine soil particles eroded from the highlands, as we discuss in this study.

2. Material and methods

2.1. Study area and soil sampling

This research was conducted in the SW in the Solok regency of West Sumatra (latitude 00° 36′ 08″ to 10° 44′ 08″ S, longitude 100° 24′ 11″ to 101° 15′ 48″ E). SW has an active volcano, Mount Talang (2500 m asl). Further information about the study area and sample locations are shown in Figs. 1 and 2. On the east side of Mount Talang, we found a lake from which water flows through the lowlands and into lake Singkarak located at an altitude of 300 m asl. All the water of rivers and tributaries that flow into the SW also drain into lake Singkarak. According to data of climatological stations from 1996 to 2000. The SW has a humid tropical climate. The rainfall rate hovers at around 1669 and 3230 mm between altitudes of 300 and 2500 m. Annual temperatures range from 19 °C to 30 °C varying from highlands to lowlands. The average annual humidity also varies from 78.1% to 89.4% (Farida et al., 2005).

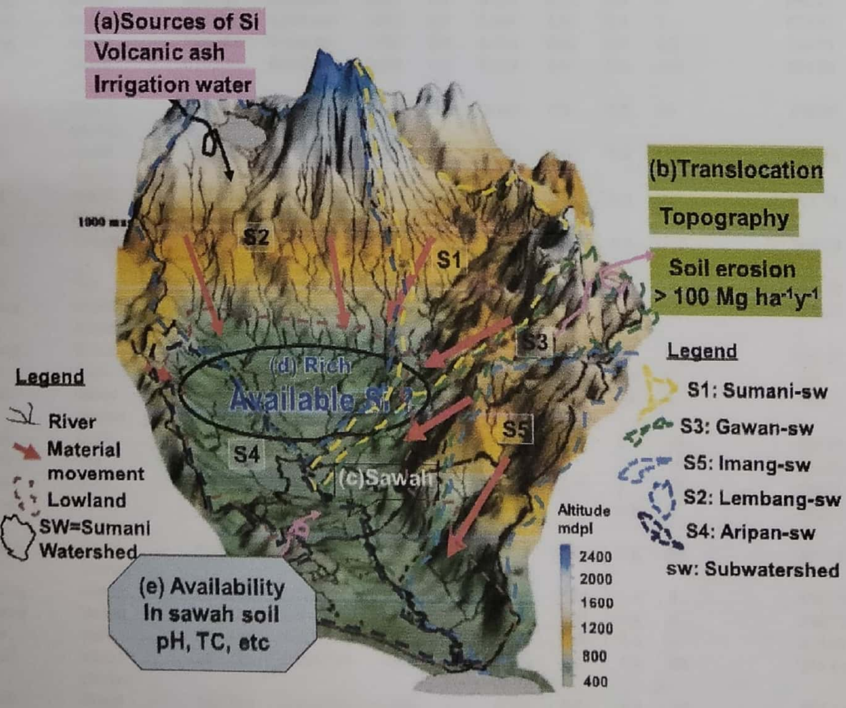

Fig. 1. Possible factors influencing the distribution of available Si in the SW. (a) Natural source of Si by volcanic ash, irrigation water and top soil. (b) Translocation of Si by topography and soil erosion. (c) Deficiency of Si in sawah soil. (d) Rich available Si in lowland. (e) Available Si in sawah soil controlled by pH, TC, etc.

Table 1
Available SiO_2 (mg/kg) and erosion-factor analyses in sampling sites in the Sumani watershed.

Location	Sub watershed	Land use	GPS reading							Erosion Mg/ha/yr	SiO_2 (0–20) mg SiO_2/kg	SiO_2 status in soil
			East	South	R	K	LS	C	P			
Jawi-jawi 1	Sumani	Sawah	681,009	9,898,946	2452	0.1	0.064	0.01	0.4	5	204.64	d
Jawi-jawi 2	Sumani	Sawah	681,007	9,898,924	2452	0.1	0.064	0.01	0.4	5	559.71	l
Jawi-jawi 3	Sumani	Sawah	680,846	9,899,016	2452	0.1	0.064	0.01	0.4	10	138.86	d
Gantung ciri 1	Sumani	Sawah	679,766	9,900,725	2452	0.3	0.001	0.01	0.4	0.1	258.86	d
Gantung ciri 2	Sumani	Sawah	679,906	9,900,722	2452	0.3	0.001	0.01	0.4	0.1	308.79	l
Gantung ciri 3	Sumani	Sawah	679,994	9,900,676	2452	0.3	0.001	0.01	0.4	5	271.93	d
Kelok Duri	Sumani	Sawah	682,301	9,909,213	2452	0.1	0.064	0.01	0.4	2	207.86	d
Selayo	Sumani	Sawah	682,677	9,909,496	2452	0.1	0.064	0.01	0.4	2.5	127.07	d
Sawah sudut 1	Sumani	Sawah	682,689	9,909,403	2452	0.1	0.064	0.01	0.4	2	201.64	d
Sawah sudut2	Sumani	Sawah	682,753	9,909,451	2452	0.1	0.064	0.01	0.4	2	200.79	d
Gawan-sungai 1	Sumani	Sawah	682,988	9,911,695	2452	0.3	0.001	0.01	0.4	15	145.5	d
Gawan-sungai 2	Sumani	Sawah	683,204	9,911,613	2452	0.3	0.001	0.01	0.4	10	146.29	d
Gawan-sungai 3	Sumani	Sawah	683,159	9,911,560	2452	0.3	0.001	0.01	0.4	15	250.71	d
Batu Banyak 1	Lembang	Sawah	690,240	9,894,285	1665	0	0.611	0.01	0.4	5	157.07	d
Bukik Sileh 2	Lembang	Sawah	690,168	9,894,089	1665	0	0.611	0.01	0.4	5	168	d
Anau kadok 4	Lembang	Sawah	690,190	9,894,077	1665	0	0.611	0.01	0.4	5	331.07	l
Bukik Sileh 4	Lembang	Sawah	690,146	9,894,586	1665	0	0.611	0.01	0.4	7.5	230.14	d
Koto Lawas 1	Lembang	Sawah	690,485	9,898,085	2452	0	1.744	0.01	0.4	0.2	148.07	d
Koto Lawas 2	Lembang	Sawah	690,385	9,898,220	2452	0	1.744	0.01	0.4	0.2	308.14	l
Koto Lawas 3	Lembang	Sawah	690,391	9,898,224	2452	0	1.744	0.01	0.4	10	241.71	d
Batu banyak	Lembang	Sawah	689,859	9,899,180	2452	0.1	0.064	0.01	0.4	15	203.57	d
Koto Anau	Lembang	Sawah	687,948	9,902,605	2452	0.5	0.064	0.01	0.4	5	124.29	d
Sawah Durian 2	Lembang	Sawah	687,963	9,902,709	2452	0.5	0.068	0.01	0.4	5	192.64	d
Sawah Durian 3	Lembang	Sawah	688,040	9,902,988	2452	0.3	0.064	0.01	0.4	5	165.21	d
Pandan Putih 1	Aripan	Sawah	684,981	9,909,986	2452	0.3	0.064	0.01	0.4	5	339.86	l
Pandan Putih 2	Aripan	Sawah	684,868	9,910,153	2452	0.3	0.064	0.01	0.4	5	249.64	d
Rawang sari	Aripan	Sawah	684,560	9,910,295	2452	0.3	0.064	0.01	0.4	5	427.07	l
Pandan ujung 1	Aripan	Sawah	685,806	9,912,702	2452	0.1	0.001	0.01	0.4	5	89.36	d
Pandan ujung 2	Aripan	Sawah	685,820	9,912,612	2452	0.1	0.001	0.01	0.4	5	164.79	d
Pandan ujung 3	Aripan	Sawah	685,664	9,912,492	2452	0.1	0.001	0.01	0.4	5	192	d
Pandan ujung 6	Aripan	Sawah	685,437	9,912,538	2452	0.1	0.001	0.01	0.4	5	184.71	d
Parambahan 1	Aripan	Sawah	690,900	9,902,399	2452	0.3	0.611	0.01	0.4	1.8	306.43	l
Parambahan 2	Lembang	Sawah	690,786	9,902,411	2452	0.3	0.611	0.01	0.4	1.8	280.5	d
Parambahan 3	Lembang	Sawah	690,734	9,902,391	2452	0.3	0.064	0.01	0.4	0.2	227.14	d
Sungai janih	Lembang	Sawah	686,383	9,898,559	2452	0.1	0.064	0.01	0.4	15	113.36	d
Gunung Talang	Lembang	Sawah	686,155	9,898,931	2452	0.1	0.064	0.01	0.4	10	162.64	d
Batu Bajanjang	Lembang	Sawah	686,201	9,898,830	2452	0.1	0.064	0.01	0.4	10	120.86	d
Air angek 1	Lembang	Sawah	684,168	9,898,356	2452	0.3	0.064	0.01	0.4	5	500.57	l
Anau Kadok 2	Lembang	Sawah	684,089	9,898,413	2452	0.3	0.064	0.01	0.4	5	139.5	d
Anau Kadok 3	Lembang	Sawah	684,138	9,898,260	2452	0.3	0.064	0.01	0.4	10	243.21	d
Pasar usang	Lembang	Sawah	684,550	9,903,109	2452	0.3	0.064	0.01	0.4	5	374.57	l
Panyalaian Cupak	Lembang	Sawah	684,404	9,903,287	2452	0.3	0.064	0.01	0.4	0.2	364.71	l
Kubu	Gawan	Mixed Garden	679,336	9,910,716	2452	0.3	2.512	0.2	0.5	640	534.86	l
Parak gadang	Gawan	Mixed Garden	680,767	9,911,154	2452	0.3	0.064	0.2	0.5	45	445.29	l
Gunung Talang	Sumani	Mixed Garden	681,796	9,902,683	2452	0.1	0.064	0.2	0.5	30	476.79	l
Gantung Ciri	Sumani	Mixed Garden	679,878	9,903,305	2452	0.2	0.064	0.2	0.5	5	211.71	d
Curang gadang sasak	Sumani	Sawah	677,000	9,902,000	2452	0.1	2.512	0.01	0.4	115	262.29	d
Kayu aro	Sumani	Tea	680,022	9,890,308	1665	0.1	0.064	0	1	20	326.79	l
Pasar usang guguk	Lembang	Mixed Garden	682,500	9,898,000	2452	6.1	0.064	0.2	0.5	45	679.07	h
Koto baru	Lembang	Sawah	683,508	9,905,910	2452	0.2	0.064	0.01	0.4	3	508.07	h
Lembang	Aripan	Bush	681,302	9,914,208	2452	0.2	0.001	0.95	0.4	1	543	h
Jawi-jawi	Sumani	Mixed Garden	679,878	9,903,305	2452	0.2	0.064	0.2	0.5	5	955.71	h
Sukarami BPTP	Sumani	Bush	680,390	9,895,606	1665	0.1	0.064	0.29	1	15	447.86	l
Danau kambar	Sumani	Tea	680,586	9,890,624	1665	0.1	0.064	0	1	15	217.93	d
Air batumbuk	Lembang	Bush	685,164	9,886,435	1665	0.2	0.064	0.29	1	85	260.79	d
Bungo tanjung	Lembang	Mixed Garden	693,126	9,883,658	1665	0.1	1.744	0.2	0.5	5	382.71	l
Air tawar	Lembang	Mixed Garden	691,000	9,887,152	1665	0.1	2.512	0.2	0.5	30	497.79	l
Bukik sileh	Lembang	Sawah	688,906	9,894,277	1665	0	2.138	0.01	0.4	5	509.14	l
Koto anau	Lembang	Sawah	687,977	9,902,100	2452	0.2	0.001	0.01	0.4	5	245.79	d
Air Mati	Aripan	Bush	684,848	9,912,166	2452	0.3	2.138	0.95	0.4	1	616.29	h
Bukik gompong	Sumani	Mixed Garden	681,722	9,895,558	1665	0.1	2.138	0.2	0.5	85	576.64	l
Kampung jawa 1	Sumani	Mixed Garden	682,165	9,894,832	1665	0.1	2.138	0.2	0.5	65	857.14	h

(continued on next page)

Table 5
Average Si concentration (mg SiO_2 L^{-1}) in irrigation and river water from Sumani Watershed, Java Island, and other Asian countries.

Study (reference)	Location	Area (km^2)	SiO_2 concentration (mg SiO_2 L^{-1})
Irrigation water in Sumani Watershed (SW)	Sumatera Island, Indonesia	583.3	32.65
River water in Sumani Watershed (SW)	Sumatera Island, Indonesia	583.3	40.94
Lake Dibawah in Sumani Watershed	Sumatera Island, Indonesia		5.96
Irrigation water in Java (Darmawan et al., 2006)	Java Island, Indonesia		14.00
River water in Java (Kawaguchi and Kyuma, 1977)	Java Island, Indonesia		29.82
River water Citarum Watershed (Husnain et al., 2008)	Java Island, Indonesia	6949	24.05
River water Kaligarang Watershed (Husnain et al., 2008)	Java Island, Indonesia	210	37.28
River water in Thailand (Kawaguchi and Kyuma, 1977)	Thailand		17.19
River water in West Malaysia (Kawaguchi and Kyuma, 1977)	Malaysia		13.01
River water in Sri Lanka (Kawaguchi and Kyuma, 1977)	Sri Lanka		13.07
River water in Japan (Kawaguchi and Kyuma, 1977)	Japan		19.00
Irrigation water in Japan (Kumagai et al., 2002)	Japan		10.20

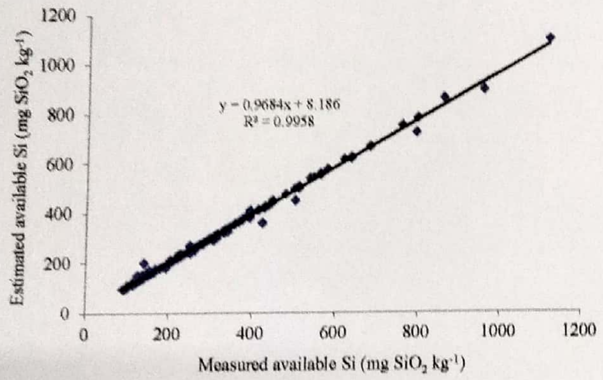

Fig. 10. Correlation between measured available Si in the laboratory and estimated value.

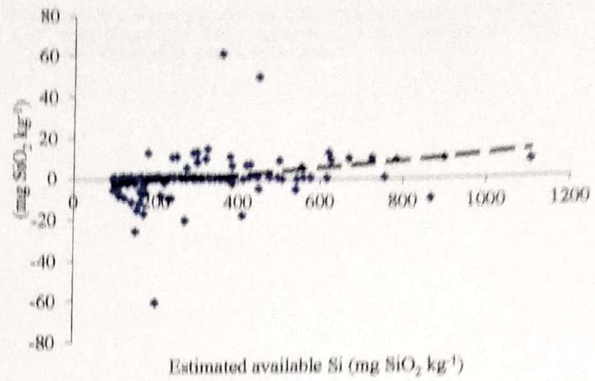

Fig. 11. Correlation between the estimated available Si and estimated error.

available Si and estimated value) and estimates of available Si. Again, this can be seen easily that the value is distributed around the horizontal straight line which demonstrates that the estimated error value is almost zero. The estimated value of the large error did not depend on the actual estimated values.

4. Discussion

According to Matichenkov and Calvert (2002) and Sumida (1992), available Si at <600 mg SiO_2 kg^{-1} and <300 mg SiO_2 kg^{-1} is considered to be low and deficient, respectively, for growth and rice production. As shown in Table 1, the USLE C factor in the paddy field is the smallest value compared with other plants, and the estimated soil erosion is also small. Table 1 shows that the natural causes of erosion in the SW are due to the large R, K and LS values of the USLE factor. Soil erosion in the SW can be controlled by reducing the parameters of USLE C and P factors. In general, Si is available in sawah soils at deficient levels. The erosion status is also low. The available Si in soils ranges from deficient to low levels, indicating that the status of soil erosion in sawah is so low that it does not have a significant effect on the cause of available Si in sawah soils at the level of definition (<262.4 mg SiO_2 kg^{-1}). This means that the available Si is more influenced by the practice of rice management.

Si concentrations are generally available in the SW at low to deficient levels. From 77 samples of sawah soil at a depth of 0–20 cm, 83% concentration of available Si in soils was found at a deficient level, 17% at a low level and 0% at a high level. Deficient levels of available Si in the soil are found in subwatershed Lembang (S2), Sumani (S1), Aripan (S4), Imang (S5) and Gawan (S3). Significant Si deficiency has occurred in the sawah in the SW (Table 1). Thus, adding Si in the form of fertilisers is needed in sawah. The aim is to increase sawah production by more than 5 tons ha^{-1} to 9 tons ha^{-1} (Aflizar et al., 2019).

Table 1 shows that the available Si concentrations in soil > 600 mg SiO_2 kg^{-1} are found in mixed gardens, forests and shrubs in sub-watershed Lembang (S2), Sumani (S1) and Aripan (S4) because these plants do not need much Si for production. According to Ma et al. (2007), sawah desperately needs available Si in the soil for growth, production and protection against diseases. Sawah has deficient levels of Si due to intensive rice farming (3 times a year), burning of straw and the absence of Si return in the form of fertiliser to rice fields (Darmawan et al., 2006).

The available Si concentration in sawah, vegetables and shrubs is less than 300 mg SiO_2 kg^{-1}, indicating that the sawah level is deficient. This is a sign why in sawah soils Si deficiency affects production and blast disease (Aflizar et al., 2009), whereas in mixed gardens and forests, vegetables and tea do not show a significant effect because sawah are Si accumulator, whereas other agricultural crops are not.

The concentration of DSi in water in the SW is higher because in SW there is additional Si from volcanic ash of Mount Talang (Fiantis et al., 2010) and warm springs that have high DSi water content, which are located in the highlands of SW (Somura et al., 2017). Therefore, to increase rice production in SW, the Si should be more than 5 tons ha^{-1} to 9 tons ha^{-1}, and blast disease in rice fields should be eliminated. Based on the data in Tables 2 and 5, Si management is needed in sawah soil in the form of Si fertiliser because there is not enough natural contribution of Si from topsoil and DSi from irrigation water, river water and sediments to reach available Si at concentrations of > 600 mg SiO_2 kg^{-1}. To achieve sustainable Si management in sawah, an average addition of Si fertiliser of 165 kg SiO_2 ha^{-1} is required.

At present, the Si deficiency in sawah soils can no longer be improved from natural fertilisers sourced from irrigation water, river water and

Warsi, O.M., Dykhuizen, D.E., 2017. Evolutionary implications of Liebig's law of the minimum: selestion under low concentration of two nonsubstitutable nutrients. Ecol. Evol. 7, 5296–5309.

Wischmeier, W.H. & Smith, D.D. 1978. Predicting rainfall erosion losses: a guide to conservation farming, USDA Handbook: No. 537 US Department of Agriculture, Washington, DC. p 1-58.

Wu, L., Beard, B.L., Roden, E.E., Johnson, C.M., 2009. Influence of pH and dissolved Si on Fe isotope fractionation during dissimilatory microbial reduction of hematite. Geochim. Cosmochim. Acta 73, 5584–5599.