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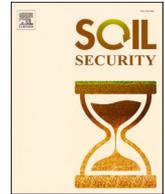
Research in Soil Biology is a major activity within the School of Agriculture and Environment at The University of Western Australia. Our emphasis is on understanding the activities of a wide range of soil organisms in the context of their contribution to important soil processes. My areas of speciality include soil biological fertility, the roles of arbuscular mycorrhizas in plant nutrition and soil health, the effectiveness of soil bio-amendments, and the impacts of land management practices on root growth and nutrient cycling. We are interested in soil health and the roles of soil organisms in natural ecosystems as well as in agriculture/horticulture and disturbed environments such as minesites

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The increasing role of Indonesian women in soil science: Current & future challenges

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ABSTRACT

Gender equality is one of the UN sustainable development goals less discussed in soil science in Indonesia. There is limited information regarding soil science education, and the role of women in Indonesia. This study aimed to provide an overview of the issue of gender equality in Indonesian soil science. We surveyed the number of women soil science students, lecturers, and researchers from 2016 to 2020. Twenty-seven soil science undergraduate programs were identified across government-owned universities in Indonesia. The number of students in soil science is steadily increasing in the last five years, each year with about 1500 new students enroll in soil science. The number of female students also increased with an average proportion of 55% in 2020. However, the number of women academics was only 30%, representing a disproportion of gender equity. The Indonesian soil science society had 35% women members. Students still perceive soil science would be better taught by men lecturers as it involves fieldwork. Nevertheless, more students preferred to be supervised by women lecturers. Our data also revealed that women academics had less opportunity to receive Ph.D. degrees, became professors, and occupied leadership positions in the university. We discuss barriers that hinder women's academics careers in Indonesia, including social and cultural values and organizational barriers. Soil science academics should prepare a gender-equal soil science workforce to the growing population. Thus, supporting the Indonesian soil scientists' women and achieving a more gender balance target is vital for accelerating soil science education, enhancing research opportunities, and managing agriculture to support economic growth.

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1. Introduction

Soils are natural resources that have critical roles in supporting the life and survivability of our planet. In 2015, the United Nations set up sustainable development goals with combatting poverty and eradicating hunger as the top two priorities. Other SDGs related to soil science include 3 (Good Health and Wellbeing), 5 (Gender Equality), 6 (Clean Water and Sanitation), 7 (Affordable and Clean Energy), 9 (Industry Innovation and Infrastructure), 11 (Sustainable Cities and Communities), 12 (Responsible Consumption and Production), 13 (Climate Action), and 15 (Life on Land) (Lal et al., 2021). This implies more nutritious and safe food should be produced from productive and healthy soils. In addition, all nations should promote soil security and food systems to achieve sustainable development goals (Reddy et al., 2021; McBratney et al., 2014). Yet, many developing countries, including Indonesia, invested less than 1% of their GDP in research. Still less discussed is SDG 5 (Gender Equality), the provision of fairness and justice in the distribution of benefits and responsibilities between women and men. Gender equality is now just started being discussed in the soil science community (Brevik et al., 2021)(Vaughan et al., 2019). Studies have found a lack of gender balance and low diversity and insufficient inclusion in soil science compared to other subdisciplines within the agricultural, earth, and natural sciences (Carter et al., 2021). Soil scientists, men, and women of all background should have an equal opportunity to implement their expertise in sustainable soil management to reach SDGs. Institutions of education and research centers should continuously generate young soil scientists to tackle the soil problems associated with soil productivity and ecosystem services.

Indonesia, the 4th most populous nation has 270 million people in 2019 and an annual population growth rate of 1.1%. It needs to produce more food challenged by a shrinking arable land area and climate change. The role of young women scholars seems to have been given less attention in the past, and more opportunities are given to young men. But there is a growing trend that younger women scholars interested in soil science than men. Hence, the expectation for future soil management and soil productivity to feed continuously high population pressure worldwide need to rely equally on women's shoulders. The challenges are working together as a global soil partnership to promote sustainable soil management and raise awareness to combat soil degradation and environmental problems.

The 2020 UNESCO report found that the involvement of women in science as researchers in the world varies between 8 and 63%, with an average value of 30% (UNESCO, 2021). The lowest percentage of women as researchers is in Ethiopia, whereas Bolivia has the largest share of women researchers. In addition, the report reveals the gender gaps in the pipeline leading to a research career, the decision to pursue higher education (doctorate degree), and the conflict face by women to choose career ambitions with family-caring responsibilities (UNESCO, 2020, 2021). But little information is available on the role and share of women in science in Indonesia.

Indonesian women have vital roles in their families and society. Indonesian women make a substantial contribution to agricultural production as a labor force as well as in education. Women education and women's rights in Indonesia were advocated by Raden Adjeng Kartini (Hawkins, 2014). Kartini was born in an aristocratic Javanese family on April 21, 1879. She only attended a Dutch-language primary school and was forbidden from pursuing higher education when she reached the age of twelve. Her letters, published in 1911, urged the Dutch colonial government to improve the young girls' education, which led to emancipation or gender equity. However, as we will discuss later, the Dutch did not provide many educational opportunities to Indonesian.

Indonesian women accounted for 49.42% of the national population according to the national census in 2020, yet their participation and involvement in science in general and soil science (education and research) are less discussed. It is unrepresented in the global soil science

society survey of Dawson et al. (2021). In physics, Indonesian women only made up 26% of its national society (Raharti and Kartini, 2014). This paper assesses the involvement and share of Indonesian women in soil science, their leadership, their involvement with young and future generations of soil scientists, and future challenges. We will discuss gender equality and equity in Indonesian soil science. Gender equality is providing men and women with the same equal opportunities while gender equity is giving women the tools and support to succeed (Shannon et al., 2019). This paper first reviews the history of soil science and its education in Indonesia to provide the context. Then we provide a survey of the distribution of women studying soil science, women in academics, research and soil science community. We provide a survey on the issue of gender equality from undergraduate students and academics. Finally we provide a discussion and recommendation to address gender equity in Indonesian soil science.

2. A brief history of soil science in Indonesia

A brief timeline of the history of soil science in Indonesia is given Fig. 1. Soil science in Indonesia was initiated by E.C.J. Mohr (1873–1970), a Dutch colonial chemist who worked at the Botanic garden in Buitenzorg (now Bogor) in 1898. In 1905, Mohr founded *Laboratorium voor Agrogeologie en Grondonderzoek* or the Agrogeology Laboratory as part of the botanical garden to increase knowledge of soil (*Laboratorium tot Vermeerdering de Kennis van den Bodem*) (Tan, 2008). Another group of scientists who studied soils was the chemists. Notably, D.J. Hissink (1874–1956), a Dutch chemist who worked in Deli, North Sumatra in 1900–1903, analysing soil for its chemical content for soil fertility evaluation for Dutch tobacco plantations (Minasny et al., 2020b). Hissink was later appointed as the Secretary-General of the International Society of Soil Science (ISSS, the precursor of the current International Union of Soil Sciences) in 1924. In colonial times, soil research focused on supporting the extractive European economy, increasing the profit of the industrial crops owned by European companies.

Mohr initiated the first Soil Congress in Indonesia (*Bodemcongres*) held in Jogjakarta on October 25–28, 1916. Mohr's research focused on understanding the distribution of soil in Java and Sumatra, which were mainly derived from volcanic eruptions (Fiantis, 2019; Minasny et al., 2021). He grouped soils based on climate, temperature regime, and parent material. The agrogeological approach distinguished soils of a region mainly from their parent materials, which works very well for soils derived from various volcanic activities (Fiantis, 2019). The parent material of the soil was determined using petrography mineralogical observations. Mohr described the soils of Indonesia in *De bodem der tropen in het algemeen, en die van Nederlandsch-Indië in het bijzonder*, which was published in two volumes in 1932 and 1938 (Mohr, 1944).

Research centers were also set up in various regions of Indonesia for specific crops. They usually had a component of soil chemistry researching soil fertility improvement. These include tea, tobacco in Deli, rubber, sugar, rice, cinchona, etc. There were also experimental stations in Central and West Java. All research led by Dutch scientists was directed to benefit the colonial government and economy by exploiting natural resources. There was little attention to research for food production to support the indigenous population. The extent of Indonesian contribution to the early soil science research through local knowledge, sample collection and sample analysis was completely ignored (Minasny et al., 2020a).

The agrogeology laboratory in Bogor changed its name to *Bodemkundig Instituut* (Soil Science Institute) in the late 1920s headed by John Thomas White. During the Japanese occupation in 1942–1945, the name changed to *Dozyoobu*. There was not much activities during Japanese occupation as the Japanese were extracting resources through force labor to fund the war. After the war, F.A. van Baren was appointed as the director of the Soil Science Institute in Bogor in 1947. Van Baren later became Secretary-General of the ISSS in 1950–1975. The soil

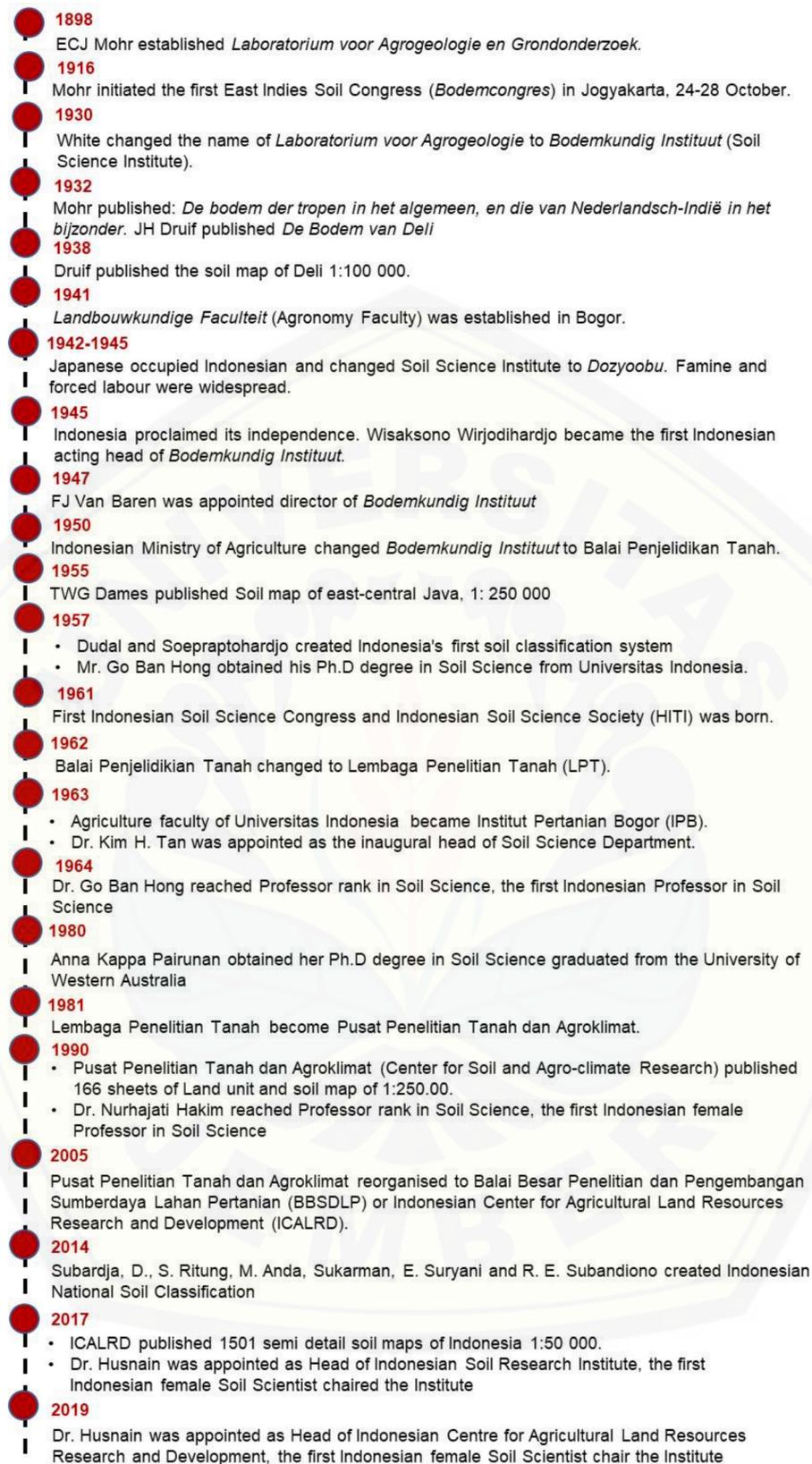


Fig. 1. Indonesia Soil Science timeline.

research institute continued to conduct soil surveys and mapping using the agrogeological approach as the Dutch were against the American system (Tan, 2008). Dames (1955) published soils of east-central Java with a 1: 250,000 soil map legend of soil groups based on specific soil-forming factors, such as Lateritic soils, Podzolized lateritic soils, Humic mountain soils, Margalite soils, and bleached Soils. The Soil Science institute changed its name to *Balai Penyelidikan Tanah* in 1950 and underwent various name changes.

The agrogeological approach was superseded by the USDA and FAO system. In 1957, Rudi Dudal from the FAO and M. Soeprahardjo introduced the then "modern" soil classification system and created Indonesia's first soil classification system (Dudal and Soeprahardjo, 1957). The soils were identified as Great Groups (Soeprahardjo and Ismangun, 1980). In the 1980s, Indonesian soil scientists adopted the USDA soil classification system (Sukarman et al., 2013). Land suitability maps were produced for supporting food crops. As the USDA system was deemed not suitable for many soils in Indonesia, the Indonesian National Soil Classification was created based on a morphogenetic approach in 2014 (Subardja et al., 2016)

In 2005, the structure of the soil research institute was changed. Indonesian center for Agricultural Land Resources Research and Development (ICALRD) was formed under the Ministry of Agriculture of Indonesia. ICALRD coordinates the four research institutes: Indonesian Swamp Land Agriculture Research Institute (ISARI), Indonesian Soil Research Institute (ISRI), Indonesian Agroclimate and Hydrology Research Institute (IAHRI), and Indonesian Agricultural Environment Research Institute (IAERI).

ICALRD is in charge of research activities related to soil mapping of all Indonesian lands (about 190 million hectares) at various map scales from exploratory scale (1:1000,000) to detail scale (1:10,000), land evaluation and suitability for various agricultural crops, and make a recommendation for sustainable soil management as the basis for policymakers to determine the policies in spatial planning and land use management.

Higher education in agriculture in Indonesia started very late in the 1930s, as the Dutch colonial policy denied western education access to all Indonesians. This inhibition of western education and science severely delayed modernization in Indonesia (Geschiere, 1973). The Dutch established *Landbouwkundige Faculteit* (Agronomy Faculty) in Bogor in 1941 as part of its higher education institute, which was accessible only to a limited number of people. After the war, the *Nood-Universiteit* was founded in Jakarta in 1946 with five faculties, including medicine, law, art and philosophy, engineering, and agriculture. In 1947, its name changed to *Universiteit Indonesia*. In 1949, the agriculture faculty was gradually moved to Bogor. It is now known as *Institut Pertanian Bogor* (IPB) and was formally established in 1963 by Indonesian.

Initially, soil science was taught at the agriculture faculty (*Landbouwwetenschap*) of *Universiteit Indonesia* by Dutch scientists such as F.A. Van Baren (mineralogy and crystallography), H.J. Hardon (soil fertility), J. Schuylenborgh (soil genesis), and F.F.F.E. van Rummelen (geology and pedology). Lessons were mostly conducted in English. Eventually, they were replaced by Indonesian lecturers and in full in 1957. The first Indonesian soil science Ph.D. graduate at the University of Indonesia was Go Ban Hong in 1957, who studied the balance of mineral nutrients in paddy rice. The first soil science department at *Institut Pertanian Bogor* was established in 1963, with Professor Tan Kim Hong as department head. Tan later became a professor at the University of Georgia, USA (Fiantis, 2018).

The Soil Science Institute sponsored the first National Soil Science Congress in Bogor on December 3–7, 1961. At the conference, the soil science society of Indonesia (*Himpunan Ilmuwan Tanah Indonesia*, HITI) was founded. HITI has a President and a Secretary-General after the IUSS structure. A regular 4-year Indonesia soil science congress started in 1977. There were only 12 congresses, the last one was in Bandung in 2019. (Hairiah et al., 2022) review the 150 years of soil science

publication in Indonesia.

3. Soil science at university in Indonesia

University in Indonesia traditionally offers soil science as a study program at the Faculty of Agriculture. There are currently 27 universities in Indonesia that offer soil science as a study program (Table 1) and distributed along the Indonesian archipelago (Fig. 2). This form of arrangement has been established since the 1960s. Prior to 1986, agricultural science undergraduate students in university had to choose a specialization or study program (such as soil science, including agronomy, plant breeding, pest management, etc.) at the third year of their study. In 1986, high school student graduates directly chose a study program like soil science in the Faculty of Agriculture when they took the university entrance exam. In 2007, the higher education director-general of Indonesia merged agronomy, plant pests and

Table 1

History of soil science education in Indonesia.

No.	University	Year soil science was first established	Location	Soil Science in the University structure
1.	Gadjah Mada	1960	Yogyakarta	Department
2.	Sumatera Utara	1960	Medan, Sumatera Utara	Agrotechnology
3.	Lampung Mangkurat	1960	Banjarmasin, South Kalimantan	Program Study
4.	IPB	1963	Bogor, West Java	Program study
5.	Andalas	1968	Padang, West Sumatra	Department
6.	Sriwijaya	1972	Palembang, South Sumatra	Department
7.	Sam Ratulangi	1973	Manado, North Sulawesi	Program study
8.	Brawijaya	1975	Malang, Jawa Timur	Department
9.	Syiah Kuala	1976	Banda Aceh, Aceh	Agrotechnology
10.	Jember	1976	Jember, East Java	Department
11.	Padjadjaran	1977	Bandung, West Java	Department
12.	Lampung	1984	Bandar Lampung	Department
13.	Bengkulu	1995	Bengkulu	Program study
14.	Hasanuddin	1980	Makassar, South Sulawesi	Agrotechnology
15.	Mulawarman	1981	Samarinda, East Kalimantan	Agrotechnology
16.	Taduluko	1981	Palu, Central Sulawesi	Agrotechnology
17.	Jambi	1983	Jambi	Agrotechnology
18.	Jenderal Sudirman	1983	Purwokerto, Central Java	Agrotechnology
19.	Sebelas Maret	1984	Surakarta, Central Java	Program study
20.	Udayana	1984	Denpasar, Bali	Agrotechnology
21.	Pattimura	1984	Ambon, Maluku	Program study
22.	UPN Veteran Yogyakarta	1985	Yogyakarta	Program study
23.	Mataram	1986	Mataram, NTB	Program study
24.	Tanjung Pura	1992	Pontianak, West Kalimantan	Program study
25.	Halu Oleo	1997	Kendari, South east Sulawesi	Program study
26.	Papua	2001	Manokwari, West Papua	Program study
27.	Khairun	2003	Ternate, North Maluku	Program study

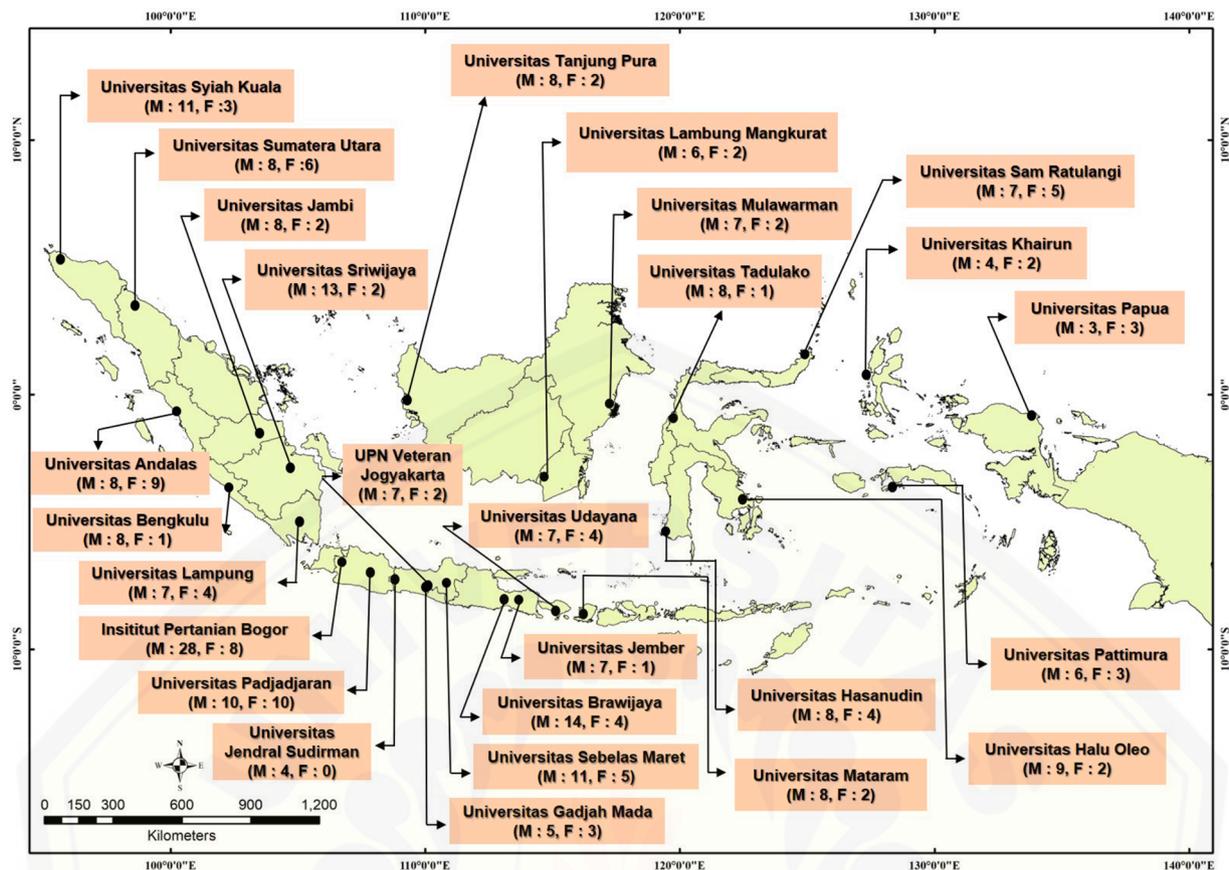


Fig. 2. Government-owned Universities that offer undergraduate and Graduate Soil Science Degree Program.

diseases management, soil science into a single Agrotechnology study program. This merger caused soil science to lose its identity. Three years later, with the help of the Indonesian soil science society (HITI), the individual soil science department submitted a proposal to the Directorate General of Higher Education, Department of National Education to re-establish soil science as an independent department or program of study. As a result, 17 out of 27 universities now are offering bachelor's degree that prepares students for a career in soil science and agriculture. All of Soil Science departments are under the Faculty of Agriculture.

4. Data collection

We collected data on undergraduate students, lecturers, and researchers data from 2011 to 2020 from respective institutions by contacting each of the soil science departments or agrotechnology study programs. The 27 government-owned universities are located in Sumatra (Syiah Kuala, Sumatera Utara, Andalas, Sriwijaya, Jambi, Bengkulu and Lampung), Java (IPB, Padjadjaran, Gadjah Mada, UPN Veteran Yogyakarta, Sebelas Maret, Jendral Sudirman, Brawijaya and Jember), Bali (Udayana), Nusa Tenggara Barat (Mataram), Kalimantan (Tanjung Pura, Lambung Mangkurat, Mulawarman), Sulawesi (Hasanuddin, Tadulako, Halu Oleo, Sam Ratulangi), Maluku (Pattimura, Khairun) and Papua. Gender data of the Indonesian soil science society (HITI) members were provided by HITI secretarial office.

Two different questionnaires were distributed to (1) students and alumni and (2) Indonesian women soil scientists (academia and researcher) through Google form. The answers from questionnaires were analyzed with WordClouds (<https://www.wordclouds.com/>) to select dominant keywords. The survey was followed up with in-depth online interviews with selected women professors and doctors.

All data used in this paper were completed on July 10, 2021. Information on research and publication achievement of the Indonesian

women soil scientists was searched and extracted from the Scopus database.

5. Results

5.1. Women soil scientists representation at the Indonesian soil science society

There are 19 Indonesian soil science society (HITI) chapters across Indonesia. The members of HITI were lecturers, researchers, employees, and consultants. The percentage of women members across the chapters ranged from 14 to 46%, with an average of 32%. The gender balance of Indonesian women in soil science was slightly higher than the British Society of Soil Science (29%), and Soil Science Society of America (31%) (Dawson et al., 2021; Vaughan et al., 2019). The global percentage of women in soil science societies varies from 0% to 69%, with an average of 32% (Dawson et al., 2021). Our data indicate that the percentage of women in Indonesia was higher than the average in Asia (26%), close to North America (31%) and the global average.

5.2. Number of soil science students

Twenty-seven government-owned universities in Indonesia offer bachelor's degree programs in soil science. The overall number of soil students was growing over the last decade from an average 30 students per university in 2011 to 70 students in 2020 (Fig. 3). The increasing trend of student enrollment in soil science is encouraging as new generations are trained in this field. The University of Brawijaya has the largest number of soil science students, with over 100 students per year since 2012, and 188 students in 2015. Based on our data, 1500 to 2000 soil science students were graduating each year in Indonesia. The opportunity for female students graduated from soil science to become

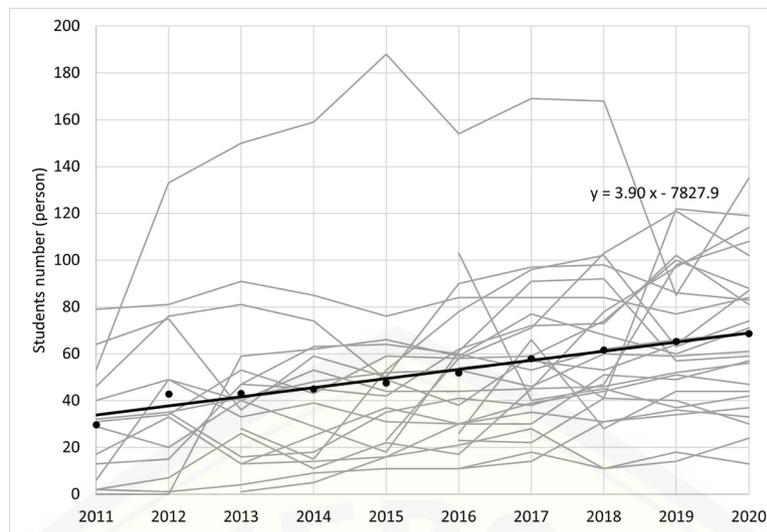


Fig. 3. Total number of soil science students from 2011 to 2020 from 27 universities (lines). The dots represent the mean number of students per year, and the red line is a linear regression over all data. Detailed data is provided in Supplementary Materials. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

lecturers is increasing with time from 1980 to 2020 but they were less than 1% out of total student outputs.

This trend differs from the USA, where Brevik (2019) reported that the total number of student enrollment in soil science programs had declined about 42% over the past 12 years. Soil science education program in the USA has undergone significant changes from strong connections with agriculture to focus on ecosystem, earth, and

environmental sciences (Vaughan et al., 2019). While soil science in Indonesia is still tightly linked with agriculture.

The gender distribution of female students varied between 30 and 70% across all universities, with an average value of 56%. Spatial distribution of female soil science students reflects more women students in Java > Sumatra > Sulawesi > Kalimantan > Maluku-Papua > Bali-Nusa Tenggara. There was a trend that the percentage of female students also

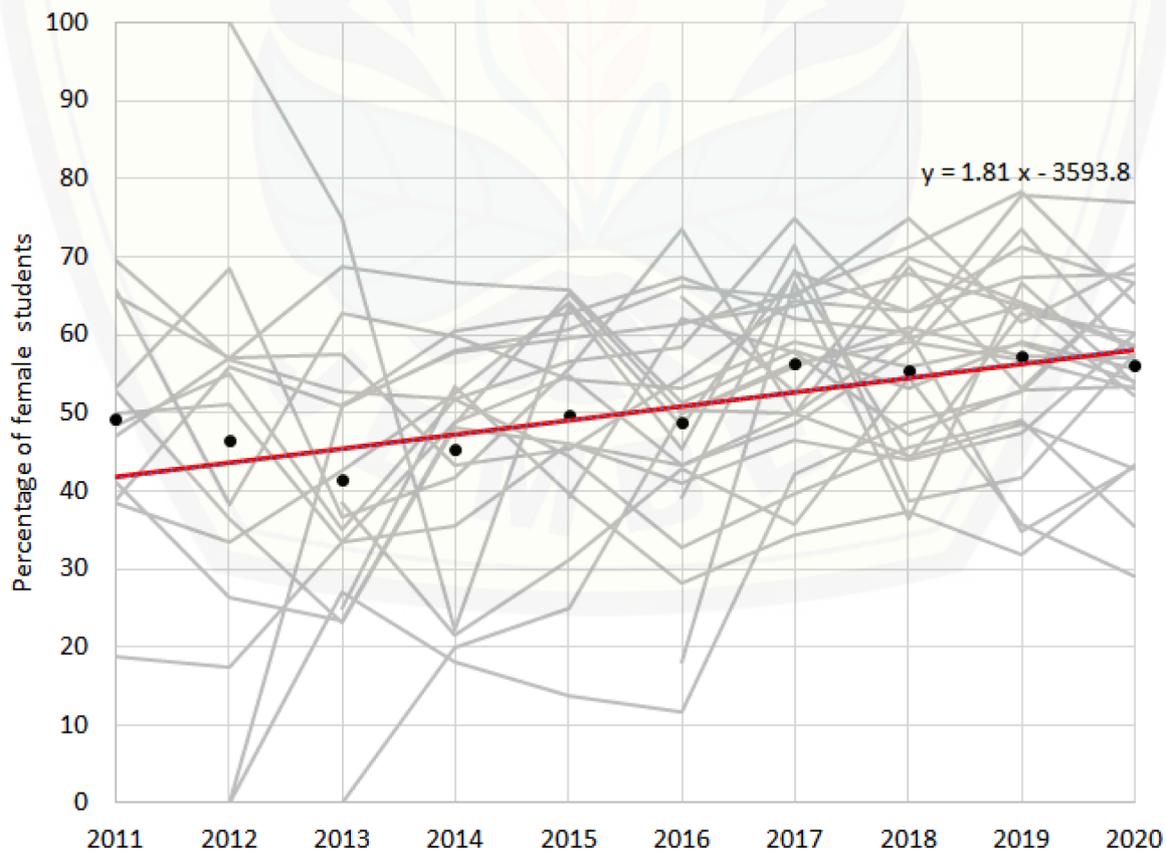


Fig. 4. Percentage of women soil science students from 2011 to 2020 from 27 universities (lines). The dots represent the mean value per year, and the red line is a linear regression over all data. Detailed data are provided in the Supplementary Materials. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

had increased from around 46% in 2011–2015 to 56% in 2016–2020 (Figs. 4 and 5). This contrasts with the USA where the percentage of women students enrolled in soil science decreased from 41 to 38% (Vaughan et al., 2019).

The trend for female being more dominant students in tertiary education in Indonesia is common in nearly all field of studies. Interestingly, proportion of male and female in lower education levels (primary to senior high schools) are relatively balanced (Badan Pusat Statistik (Central Statistical Bureau), 2020). In 2020, about 3.1 million high school students graduated every year (Data Center and Information Technology, 2020) and about 1 million of them applied for university entrance exam (Handini, 2020). But only 38% of the high school student graduates that can be enrolled to tertiary education after passing the university entrance exam.

Senior high school graduates in Indonesia are mostly 18 years or older (Badan Pusat Statistik (Central Statistical Bureau), 2020), and qualified as job seekers. Probably, more male graduates entered job market and female graduates tend to continue with tertiary education.

5.3. Women soil scientists in academia

As of June 2021, there were 551 soil science lecturers across the 27 universities in Indonesia, with an average student: lecturer ratio of about 4:1 per academic year. The number of Indonesian soil science faculty was slightly higher than in the USA, where there were 535 academics from 74 universities with soil science degree programs (Vaughan et al., 2019).

However, the gender balance in students was not reflected by the gender distribution in lecturers. The graph (Fig. 6) shows that across 27 universities, only 6 universities (Sumatera Utara, Andalas, Lampung, Padjajaran, Sam Ratulangi, Papua) had women lecturers > 40%. Moreover, 5 universities (Bengkulu, Jendral Sudirman, Mataram, Tadulako, Pattimura) had less than 20% women lecturers. Overall, the average percentage of women lecturers was 30%, consistent with many parts of the world. The percentage of women lecturers from 2016 to 2020 (Fig. 7) remained unchanged, around 30%, despite the increase in female students' ratio.

The spatial distribution of the soil science lecturers reflects more women lecturers in universities located in Java; they were 57 (10%) compared to Sumatra 51 (9%), Sulawesi 20 (4%), Kalimantan 17 (3%),

Bali, and Nusa Tenggara 11 (2%), Maluku and Papua 10 (2%).

Soil science in Indonesia is still dominated by men. It was not until 1980 when the first woman soil scientist in Indonesia obtained a Ph.D. degree from The University of Western Australia (Pairunan, 1980). Dr. Anna Kappa Pairunan was from University of Hasanuddin obtained her Ph.D. degree 23 years following the first Ph.D. degree awarded to man soil scientist (Dr. Go Ban Hong) in 1957 from Universitas Indonesia. The number of women lecturers with a Ph.D. degree increased to 92 (16%) after 41 years (2021), while men lecturers with a Ph.D. degree were much higher, with 230 (42%) after 64 years. This disparity in academic degrees between men and women is common in academia because women tend to lose their career time to family. Only one university was without a women Ph.D. degree lecturer, but Universitas Andalas and Universitas Padjadjaran had 53% and 50% of women Ph.D degree lecturers (Fig. 8).

The career of lecturers in Indonesia has the following path: assistant, lecturer, senior lecturer, and professor. The first woman soil scientist that reached the professor rank was in 1990 from Universitas Andalas (Humas dan Protokol Unand, 2015) and it was 26 years after Dr. Go Ban Hong reached the professor rank in 1964. Prof. Dr. Ir. Nurhajati Hakim retired in 2014 (Hakim, 2015). In 2020, 19 women successfully advanced to the rank of professor compared to 68 men professors. Women professors remain underrepresented, only 3% of soil science academics, while men professors accounted for 12%. The women professors were distributed only in 12 universities, while the men professors can be found across 20 universities. There was an exception, women professors at Universitas Andalas surpassed the number of men professors in 2020. Nine universities only have men professors compared to only 1 university which has only one woman professor (Fig. 9). There are some geographical variations, universities in Sumatra having more women professors compared to universities in Java, Bali, Nusa Tenggara, Kalimantan, and Sulawesi. In 2020, leading universities in West and Central Java like IPB, Padjadjaran, and Gajah Mada had yet to have a woman professor.

This discrepancy was also observed in structural position from head of department, Dean and Rector position. The highest leadership position of women was Vice-Rector ($n = 1$ out of 27), Director of Post-graduate School ($n = 3$ out of 27), Dean ($n = 2$), Vice Dean ($n = 7$), department heads ($n = 7$), department secretary ($n = 5$). This further illustrates that women are under-represented at all leadership levels.

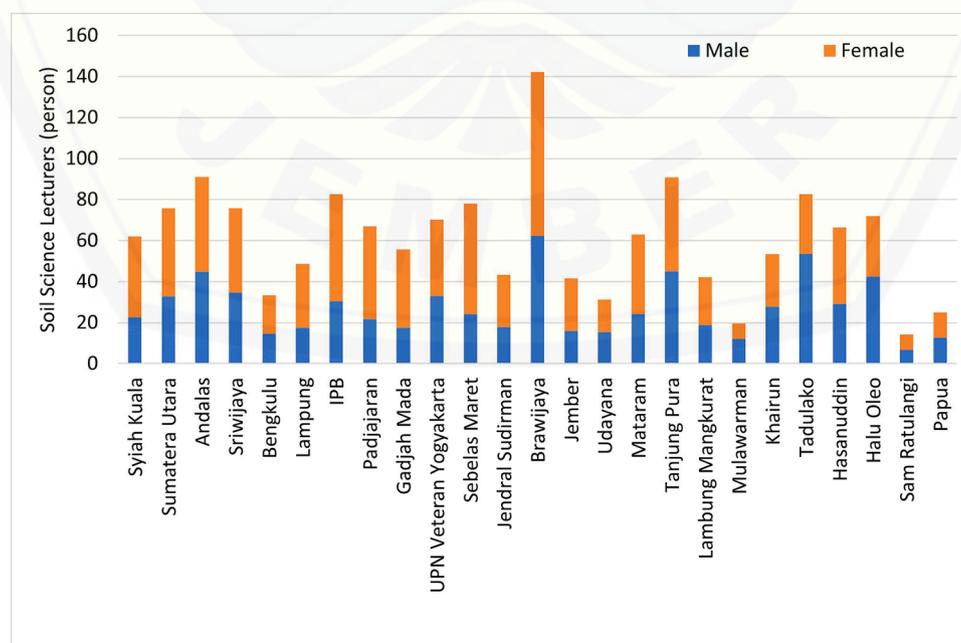


Fig. 5. The average number of soil science students in 27 government universities from 2016 to 2020.

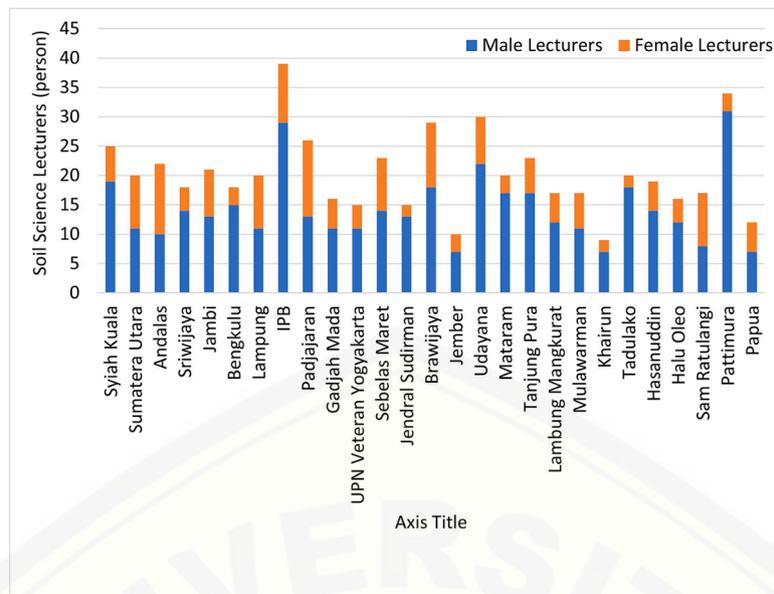


Fig. 6. Number of soil science lecturers in 27 government universities from 2016 to 2020.

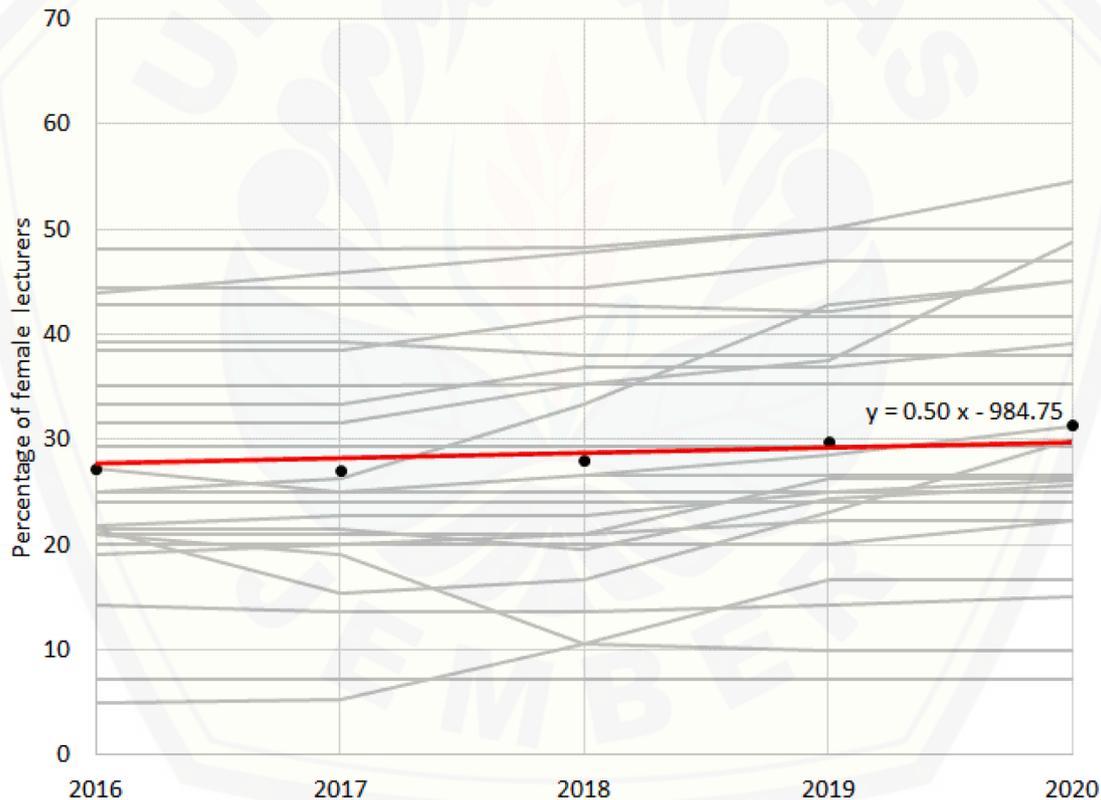


Fig. 7. Percentage of women lecturers from 2016 to 2020 from 27 universities (lines). The dots represent the mean value per year, and the red line is a linear regression over all data. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

Examining metrics of academic performance, such as H-index, number of publications, number of citations, and years of active research, the women professor in Universitas Brawijaya lead with H-index of 17, follow by one women professor in Universitas Sebelas Maret (8) and one in Universitas Andalas (7). Overall, the H-index of Indonesian women professors was still low, ranged from 1 to 17 as of June 2021.

5.4. Women soil researchers in governmental research institutes

The number of soil researchers in five Governmental Research Institutes related to soil in 2020 was 130 persons, of which 63 men (48%) and 67 women (52%) (Fig. 10). This indicates women soil scientists were slightly higher than men. The institutes include Indonesian Center for Agricultural Land Resource Research and Development (ICALRD), Indonesian Swampland Agriculture Research Institute (ISARI), Indonesian Soil Research Institute (ISRI), Indonesian Agroclimate and

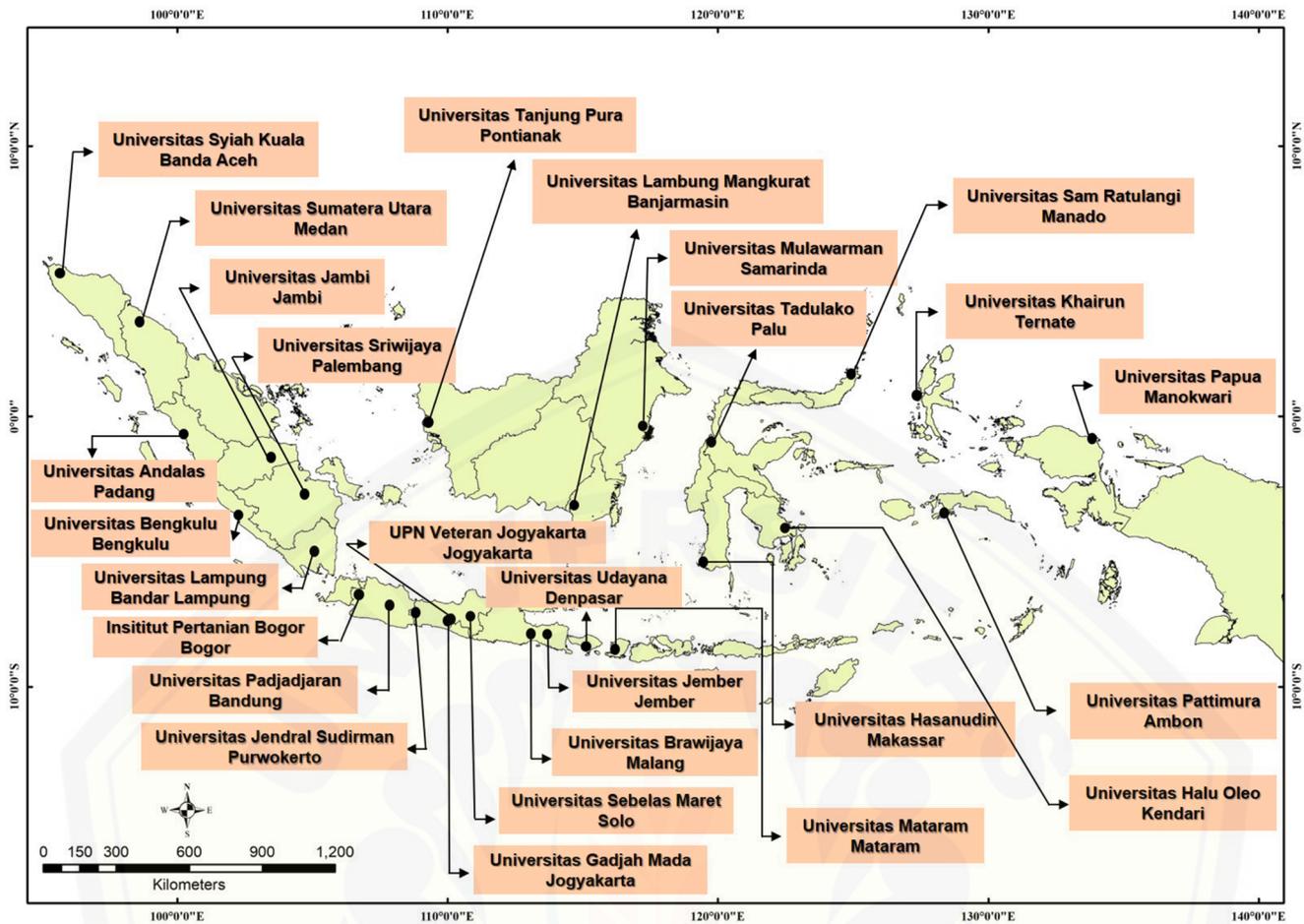


Fig. 8. Spatial distribution of soil science lecturers with Ph.D degree in 27 government-owned universities from 2016 to 2020.

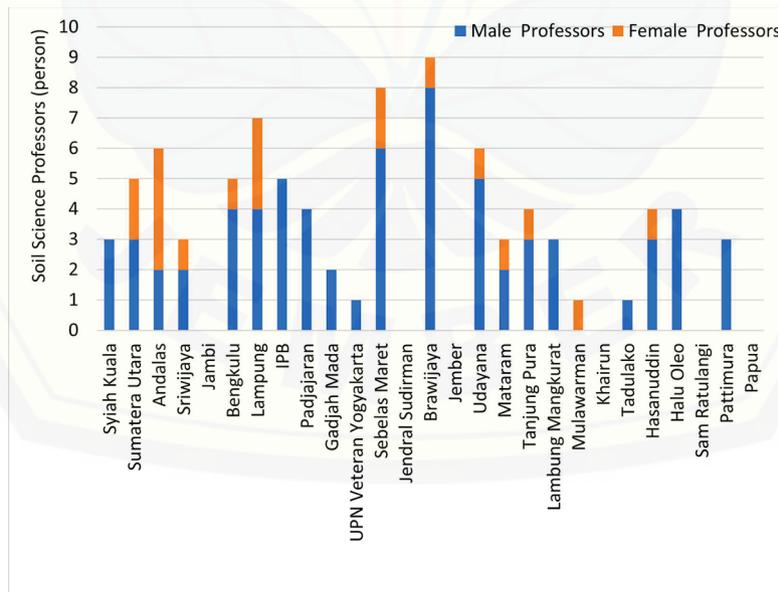


Fig. 9. Distribution of soil science Professor in 27 government-own universities from 2016 to 2020.

Hydrology Research Institute (IAHRI), and Indonesian Agricultural Environment Research Institute (IAERI). As discussed in Section 2, hierarchically, ICALRD is the leading institute to manage and coordinate the program of research activities and development of the other four institutes.

Previously soil researchers at ICALRD and its coordinated institutes were dominated by men, but over the last three years, the new employees were dominated by women who passed the selection processes. In addition, many senior soil researchers are retiring, and at the same time, the new recruitment is dominated by women.

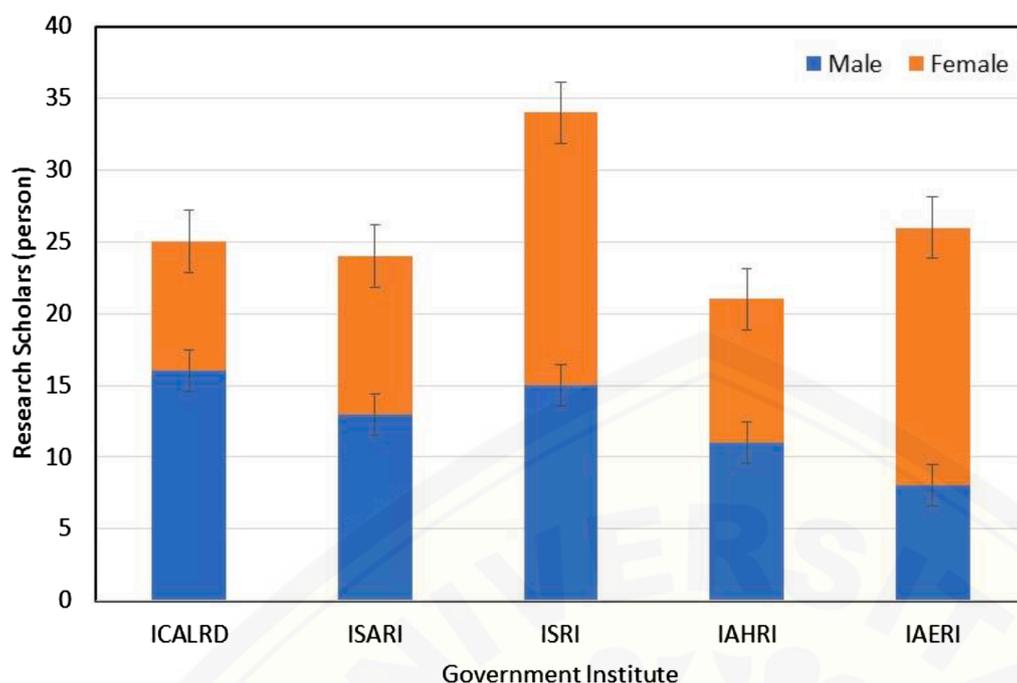


Fig. 10. Number of soil research scholars in five government research institutes in 2020.

ICALRD= Indonesian Center for Agricultural Land Resource Research and Development,
 ISARI = Indonesian Swampland Agriculture Research Institute,
 ISRI= Indonesian Soil Research Institute,
 IAHRI= Indonesian Agroclimate and Hydrology Research Institute,
 IAERI= Indonesian Agricultural Environment Research Institute.

It was not until 2013 that the Indonesian Soil Research Institute was chaired for the first time by a woman by Dr. Sri Rochayati. While in 2019 Dr. Husnain was appointed to lead IICALRD. She became the first female soil scientist in that position. She wrote that as a leader in the institute she should have a wide perspective on many programs to manage land resources, increase soil productivity and maintain the sustainability of all factors related to soil and land resources. She has to control more of her feeling and emotion to lead the institute and think logically. She believes that she can perform her duties as well as any other male leaders and brings positive outcomes to lead IICALRD, such as managing the soil and land resources rationally.

5.5. Undergraduate students view of gender issue in academics

A total of 781 students responded to our survey. They were from Brawijaya, Jember, Lampung, Andalas, Gadjah Mada, Sumatera Utara, Padjadjaran, Tanjung Pura, UPN Veteran Yogyakarta, Hasanuddin, Sriwijaya, Bogor, and Papua universities. They represent a large geographical spread from Sumatra in the west to Papua in the eastern archipelagos.

The gender distribution was 370 Men (47%) and 411 Women (53%), similar to the overall gender balance (Fig. 3). The students were studying chemistry & fertility of soils (31%), pedology and soil survey (24%), soil conservation & physics (18%), soil biology (18%), land reclamation (4%), pedometrics, modeling, precision agriculture (3%) for their final year project assignment.

The main reason for choosing soil science as a specialization was: 46% for job opportunities, 39% because it had interesting subjects, 4% were recommended by alumni, and the rest were because of personal reasons. The perspectives of students on the gender of lecturers and soil science were summarized in Table 2.

From the responses, students in Indonesia preferred men over women as a lecturer (41.9%), and almost an equal representation of preferred women (29.4%) and equal/no preference (28.7%). Men preference is reflected in the question of the desired gender distribution of teaching staff, where a significant proportion of respondents (62.7%) preferred more men over women academic staff. Students who preferred more women staff were 23%, and only 6.4% considered gender equality, and 7.9% did not consider gender imbalance as an issue.

Table 2
 Students' perspectives on gender and women in soil science.

Questions	No. valid respondents	Percentage	Respondents M:W ratio
Preferred gender of soil science lecturers			
men	231	41.9	54:46
women	162	29.4	40:60
no preference	158	28.7	35:65
Preferred gender distribution among soil science teaching staff			
men > women	395	62.7	51:49
women > men	166	23.0	43:57
men = women	45	6.4	53:47
not an issue	55	7.9	38:62
Preferred gender of a final project supervisor			
men	242	39.9	62:38
women	264	43.6	33:67
no preference	100	16.5	41:59
Any challenges for women in soil science			
yes	357	51.6	42:58
no	335	48.4	49:51
Opportunities for women in national careers			
small	88	12.2	47:53
large	631	87.8	47:53

The main keywords in the preferred lecturers, irrespective of gender preference, were related to materials, easy, delivery, explanation, clear, understanding, teaching. These were general keywords about the delivery of teaching materials that affected students' preferences.

Students who preferred men lecturers included the following keywords: field, relaxed, assertive, experienced, direct, simple. In contrast, students who preferred women lecturers reasoned: detailed, patient, kind, thorough, pleasant, inclined.

Students who preferred more men than women lecturers gave the following keywords: field, knowledge, activities, lecture, practical, and experience. While students who chose more women lecturers associated with keywords: field, (teaching) materials, knowledge, teaching, patient, understanding, comprehending.

The results indicated that Indonesian undergraduate students regarded soil science was associated with masculinity due to fieldwork. They preferred men lecturers, who were perceived as more suitable in the field, assertive, relaxed, and their delivery method was direct and simple. Meanwhile, women lecturers were perceived as providing more detailed and thorough materials with pleasant, patient, and empathetic characteristics.

However, in terms of preferred supervision for a final project (thesis), a slightly higher number of students preferred women over men (43.6%). Students who preferred men supervisor was 39.9% and 16.5% stated no preference or equal. Respondents who preferred women supervisors provided the following keywords: comfortable, thorough, detailed, easy, persevere, supervision, equal, task, safeguard, free. Students who were preferred to be supervised by men were associated with the following keywords: research, field, easy, to give, being supervised, (not) complicated, assertive, consultation, discussion, flexible. We also note that more women students preferred to be supervised by women academics, and vice versa (Table 2).

There was still a stereotypic perception by students (irrespective of their gender) that men lecturers would be more suitable for fieldwork, clear in providing instructions (felt being supervised), and women were regarded as less suitable in the field, fussy, moody, and complicated. Nevertheless, women supervisors had the following positive attributes: detailed, empathetic, and more comfortable for fellow women.

Students perceived women were less suitable for fieldwork, with 52% of respondents felt that women faced obstacles in fieldwork. Students who perceived women would be challenged in the field provided the following keywords: field, research, strength, heavy, obstacle, physical, samples, equipment, alone, slightly. While those who did not feel challenges, wrote: can, research, help, learning, friends, knowledge, each other. These students did not think that being a woman would present obstacles in fieldwork and it will not interfere with their learning, as fellow students would lend a hand. Finally, most respondents see that women had a large opportunity in their career (88%).

5.5. Academia and research institute respondents

The sample included 96 women soil scientists who responded to the survey request, 81% of them are lecturers, 8% are professors, and 11% are researchers (Table 3). Most of the respondents (97%) stated there is no gender discrimination to pursue higher education and to conduct research of their fields of interest. Nine percent of the respondents

Table 3
Perception of women scientists on gender issues.

Questions	Yes	No
Do you have a fair opportunity in education	97	3
Do you have a fair treatment in research	97	3
Do you have fair opportunities in administrative position	94	6
Is gender equality an issue in your organization	33	67
Any plan/program on gender equality in your organization	24	76
Have you been selected in a leadership position in your organization	48	52

occupied an administrative or executive position in their institution. However, the respondents mentioned that women in soil science were marginalized (23%) in a leadership position, and 34% of them faced an issue related to gender equality in their organization. While most respondents regarded that they have no perceived discrimination issue in their organization, some remarked that men are often preferred in leadership roles. However, most respondents perceived that a position should be based on capacity and regarded gender as not an issue, and thus gender equity program is not required.

6. Discussions and recommendation

This study provides the first view of the gender issue in soil science in Indonesia. There is an increasing number of students studying soil science each year, and the percentage of women students was also increasing in the past 5 years. There is also evidence that Indonesian woman soil science researchers shared the same amount publications compared to men in a recent survey by (Hairiah et al., 2022). However, the proportion of women academics is only 30%, which is also reflected in the Indonesian soil science society (35% women member). Our data also reveal inequalities in women's position in the leadership roles in most Indonesian universities. This trend reflects that Indonesia is still a country with men-dominated culture. Here we discuss some challenges faced by Indonesian women scientists on the issue of gender equity.

Social and cultural values

Kholis (2017) revealed that women academics in Indonesia face multiple barriers that hindered them from advancing their professional careers. These include family responsibility, work-family time commitment, child-caring responsibility, spouse permission and restrictions, organizational and individual-related barriers.

Cultural and religious values are the most frequent challenge. The Indonesian government had addressed gender equity and women's empowerment since 2000 based on the Presidential Instruction No. 9/2000 to improve women's quality of life and the roles of women in all sectors of development. Several programmes, policies, plans, legislation, and strategies were initiated from the national to sub-regional level to empower women. But after 20 years, the challenges have not changed significantly. The social barriers in career advancement are related to family and individual issues.

Typically, women in many countries still have more family responsibilities (i.e., household tasks) than men (Huang and Sverke, 2007; Ismail, 2008). Keeping a balance between work life and family life is challenging for most working women (Winchester et al., 2006). As a result, women were more likely to prioritize family over their work. This condition results in decreasing their momentum for their career activities (Kholis, 2017). Consequently, women scientists may have less movement and time for academic activities such as research, writing papers, and other scholarly works. For working women who have children, particularly young ones, their responsibility in motherhood and child nurturing was also identified as the main factor of postponement in pursuing their study and career development, including leadership positions (Kholis, 2017).

Cultural issues can be a significant barrier. In some cultures, choosing a career could be labeled as not being a good wife or mother. Men are still regarded as the head of the family. Women need to ask for permission from their husbands before taking a higher degree or promotion in their career. This also implies for women who want to attend other non-degree professional development programs. In some cases, women are expected to follow or not ahead of the husband's career. If the husband moves to another place, the wife would need to follow, but not vice versa. A supportive husband was identified as the primary key for married women to reach the top position. With an understanding of husband and external help, married women manage to balance work life and family life. While women without a supportive spouse had to suppress their ambition to become a leader in their organization.

Nevertheless, there are matrilineal societies in Indonesia, including

Minangkabau in West Sumatra, the world's largest matrilineal society (Hananto, 2017). Some parts of West Papua also had a matrilineal culture. This is reflected in the number of women academics in Universitas Andalas (55%) and Papua (42%). The first woman soil science professor is also from West Sumatra, where women in leadership are common.

Individual-related barriers are also related to culture. In some cultures, Indonesian women are not used to speaking up on their ambition for a higher position in an organization. Despite more and more women in leadership positions, some feel they cannot be leaders due to a lack of confidence. There is a perception that being in an executive position is diplomatic but also requires confrontation. Therefore, women tend to avoid conflict and challenges.

Organizational barriers

There are also organizational barriers. As described in students' perception, soil science was seen as more suitable for men because of fieldwork. Women are significantly underrepresented in leadership positions. Discrimination against women while not allowed but implicitly observed. Men are expected in leadership roles and aspiring women often faced cultural and organizational hurdles. Kholis (2017) noted that being in the minority in the academic world and a lack of confidence impede women's leadership aspirations.

The administrative position hierarchy in Indonesian Universities is head of department, dean of Faculty, and rector. To fulfill a position, one has to be elected by peers (head of departments and dean). For the rector position, 30% of the Directorate General of Higher Education ballot is added to 70% of senate ballot. Lately, the head of soil science department at several universities is chaired by a woman as their men colleagues were not keen on what is perceived as an administrative position. The head of the department is the lowest executive position with less financial benefit but heavy load of works. Men tend to have a higher ambition to be the dean (or vice-deans) or rector (or vice-rectors) position as these positions come with generous financial benefits. The selection process for dean and rector involves a network support from colleagues with some diplomatic manoeuvre. Kholis (2017) found that Indonesian women are not familiar with such political nature and tend to avoid conflicts, which resulted in the discouragement of women pursuing a higher leadership position.

Lack of women empowerment

The ministry of women was first established in 1983, and the name changed to the ministry of women empowerment and child protection in 2009. By establishing this ministry, the Indonesian government recognized that issues regarding women empowerment should be addressed from the national level. However, significant barriers still exist, as revealed by the study on Indonesian women academics (Kholis, 2017), such as impartially implementing empowerment policy and regulations and establishing affirmative actions. Most men leader participants in the Kholis study conveyed that administering the specific empowerment for women could be sensed as undercutting women's capacity. Systematic changes are needed to leverage women's contributions in executive positions.

Challenges on lack of gender equality and social inclusion awareness

Addressing gender equality and social inclusion awareness requires an inclusive policy, commitment, and a clear understanding from all parties involved. Education is a starting point and a key factor to improve gender equality. Indonesia has achieved the Gender Parity Index (GPI) of 1.00 by 2019 for children 7–12 years old and slightly shift to 1.02 for children 13–15 years and to 1.03 for 16–18 years old. These indices were increased from 0.89, 0.78 and 0.55 of the 1970 GPI (Afkar et al., 2020). Our finding reveals the value of GPI of 1.1 for soil science students (age 19–22 years old); as such, no more women's unequal access from primary to tertiary education in Indonesia.

However, there is still a lack of awareness of gender equality and social inclusion in academia. As noted in the student survey, only 6% noted the gender equality issue. Equally, 8% of respondents answered that gender (im) balance is not an issue in teaching. There is still a view that everyone should have the same opportunity, and capacity and

performance should be the main criteria (Table 3). Unfortunately, this view does not translate into the reality that women are underrepresented and being disadvantaged in their careers. Such a notion of equal opportunity will not translate to gender equity because of the barriers to women discussed above. As noted by Carter et al., 2021, a balanced gender, diverse, and inclusive scientific community is a moral requirement. Currently, there is little effort to implement gender equity in the workplace (Table 3). Equity, diversity, and inclusion could lead to more productive teams and greater scientific innovation (Carter et al., 2021).

Concerning equity, academics in Indonesia faced legacies of colonial research called helicopter research (Minasny et al., 2020a). Researchers from rich countries flew to Indonesia and collected samples or conducted soil research in Indonesia. They benefit from local soil knowledge but do not involve Indonesian soil scientists in research. Indonesian soil scientists were often used as field hands. This is particularly rampant in research on peatlands and volcanoes in Indonesia (Fiantis et al., 2019). Having equity in gender and a diverse background soil scientists can help in tackling various socioeconomic situations that can be encountered in real-world (Jonkman et al., 2019). Having a gender-balance workforce and in leadership positions would create new ideas, productive teams, and greater scientific innovation. There is also shift in soil science research which initially focused on soil survey to the current trend in tackling crop production and environmental issues. This means that more women will participate in soil security research (Hairiah et al., 2022). We included some case studies in the Supplementary Materials to illustrate successful women soil scientists and their impact.

Recommendations

To promote gender equity and ensure that women fully lead in soil science, we recommend various policies on gender mainstreaming should be implemented and incorporated from national to local levels. Institutional interventions should address gender equality issues. These include

- (1) facilitating women to form and strengthen associations,
- (2) improving women's access to information by training more women extension staff, holding separate meetings for women farmers, and ensuring that women are fully represented in all activities. Gender issues should be widely discussed in universities and the scientific community as a whole.

The Indonesian soil science community cannot continue to assume that everyone has an equal opportunity based on achievement but did not make a commitment to tackle the gender imbalance issue. Berhe and Ghezzehei (2021) suggested that only by acknowledging and addressing the issue, we can progress with mentoring and concrete plans and outcomes

7. Conclusion

With the increasing demand of sustainable use of soil resources, women scientists can offer their knowledge in Soil Security to influence policy and providing solutions to soil problems, through a diverse range of programs. However, we first need to find out the gender balance in Indonesian soil science and acknowledge the issues of cultural and structural barriers before we can address the impact. Our data reveal an increasing trend in the enrollment of undergraduate students over the last ten years (2011–2020). More women students (55%) are studying soil science in the last five years. However, the number of women faculty members was only 30% compared to men. In addition, from all women academics, only 16% have a Ph.D. degree and only 3% was a full Professor. Thus, there is a huge imbalance of women academics to support the increasing number of students.

Soil science is key to solving planetary food security challenges, nutritional food, and climate change mitigation. Thus academics have an obligation to train a gender-equal soil science workforce to the growing population. Supporting the Indonesian soil scientists' women is

vital for accelerating soil science education, enhancing research opportunities, better managing the realcondition in soil science and agriculture to support economic growth.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.soisec.2022.100050](https://doi.org/10.1016/j.soisec.2022.100050).

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