Data in Brief 40 (2022) 107807

Contents lists available at ScienceDirect

Data in Brief

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

Data Article

Datasets for the development of hemp (*Cannabis sativa* L.) as a crop for the future in tropical environments (Malaysia)

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ARTICLE INFO

Article history:
Received 17 September 2021
Revised 2 January 2022
Accepted 5 January 2022
Available online 11 January 2022

Keywords:
Agri-environmental data
AquaCrop
Hemp economics
Industrial hemp
Land suitability assessment
NPVB
Yield potential

ABSTRACT

An evidence base was developed to facilitate adoption of hemp (*Cannabis sativa* L.) in tropical environments (Wimalasiri et al. (2021)). Agro-ecological requirements data of hemp were acquired from international databases and was contrasted against local climate and soil conditions using an augmented species ecological niche modeling. The outputs were then used to map the suitability for all locations for 12 possible calendar-year seasons within peninsular Malaysia. The most probable seasonal map was then used to generate a land suitability map for agricultural areas across 5 standard land suitability categories. Having developed the general suitability maps of hemp in Malaysia, detailed crop growth data were collected from literature and was then used to simulate an ideotype crop model (for both seed and fiber)

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https://doi.org/10.1016/j.dib.2022.107807

for selected locations across Malaysia, where detailed daily climate data and soil information were available. Following the development of a downscaled future climate dataset, a simulated dataset of yield for the future conditions were also developed. Next, the simulated seed and fiber yield data were used to create yield maps for hemp across peninsular Malaysia. An economic value and cost-benefit analyses were also carried out using data that were collected from literature and local sources to simulate the true cost and benefit of growing hemp both for now and future conditions. This data provides the first ever evidence base for an underutilized crop in Southeast Asia. All data that was generated using the proposed published framework for the adoption of hemp in the future are stored in their original format in an online repository and is described in this article. The data can be used to map the suitability at finer scales, analyze and re-calibrate a yield model using any climate scenario and evaluate the economics of production using the standard methodology described in the above-mentioned publication.

Specifications Table

Subject	Agricultural Sciences, Agronomy and Crop Science
Specific subject area	Leveraging on open data to develop evidence basis for agricultural diversification as a pathway to ensure food and nutrition security for now and in the future in tropical countries.
Type of data	Table Image Chart Graph Figure
How the data were acquired	The primary and secondary data sources are mentioned in the data description section. Deposited data is a compilation of data files, developed by applying specific data science algorithms to the primary and secondary or raw data files. The output data that were mostly in geospatial format were used to develop visualisations and aggregations. Raw geospatial data that were collected from various primary sources underwent a harmonization process to make them adaptable for the type of analysis that was performed in the main article. Please see Section 1.3 for detail description of map files and their metadata. Total climate and soil suitability and overall suitability data were generated using the Land evaluation framework for agricultural diversification using R statistical software [2–5]. Hemp grain and fiber yields were simulated using the AquaCrop model (Version 6.1). Interpolated data were mapped using ArcGIS software version 10.6 (ESRI, Munich, Germany). Computers: 1- Desktop computer with Dual-Core Intel Core i7 CPU@3.5 GHz 16GB RAM. 2- Desktop computer with Intel® Core (TM)i7–4600 U CPU@2.10 GHz with 16GB RAM 3- Laptop computer with Intel(R) Core (TM) i5 with 8 GB RAM
Data format	Raw: GEOTIFF, SHP Analysed: GEOTIFF, SHP, MXD Filtered (resampled): GEOTIFF

(*continued on next page*)

Description of data collection	Processed data were collected through analysis on various raw data files. Total climate and soil suitability and overall suitability data were generated using the Land evaluation framework for agricultural diversification using R statistical software [2–5]. Processed data were acquired following four main published methodologies to generate the final data points: 1- Agro-ecological crop suitability assessment [2] 2- land suitability analysis [6] 3- Crop model ideotyping [7] 4- Economic analysis [1]
Data source location	Institution: Crops for the Future UK (CIC) City/Town/Region: Cambridge Country: England, UK The primary data sources are mainly databases, research articles, web articles etc. However, large portion of the data were collected from: 1- International databases; Global Knowledge Base for underutilized crops [8,9], SoilGrids [10], WorldClim [11], Global Biodiversity Information Facility (GBIF) [12], Globecover [13], Global Administrative Boundary database (https://gadm.org). 2- Local providers; Observed daily rainfall, minimum and maximum temperatures of six meteorological stations of the Meteorological Department of Malaysia were purchased for the period 2010–2019. 3- Literature sources: all respected data points that were collected and cited in the main article [1]
Data accessibility	Repository name: Mendeley Data Data identification number: 10.17632/g9dnfxbvgt.2 Direct URL to data: https://data.mendeley.com/datasets/g9dnfxbvgt/2 **Instructions for accessing these data:** The data can be downloaded free of charge into any local commuter. Geospatial data can be used for visualization using any GIS software online and offline.
Related research article	Wimalasiri E.M., Jahanshiri, E., Chimonyo, V., Kuruppuarachchi, N., Suhairi, T.A.S.T.M., Azam-Ali, S.N. & Gregory PJ. (2021) A Framework for the Development of Hemp (*Cannabis sativa* L.) as a Crop for the Future in Tropical Environments. *Industrial Crops and Products*. 172: 113999 https://doi.org/10.1016/j.indcrop.2021.113999

Value of the Data

- Hemp, *Cannabis sativa* L., is one of the most controversial crops of human history, which is still illegal/ neglected in tropical countries. However, it is a billion-dollar business in some of the temperate countries. There is a growing interest in Malaysia to cultivate hemp. Present data provides all the datasets that were used to provide an evidence base for the adoption of hemp as crop for the future in Malaysia.
- Raw Suitability data (map files) can be readily used for analysing suitability for a particular area in Malaysia. Subsets can be overlaid in any geographic information system (GIS) for further analysis or combined with other information such as socio-economics data to develop further insights.
- Releasing the data ensures reproducibility, hence transparency of all analysis that was performed by Wimalasiri et al. [1]. Scientists, planners, and government bodies can delineate national and regional development plans for the development of this valuable crop in Malaysia.
- Yield simulation data, together with the calibration data [7] can be used to estimate yield for new locations and develop 'what if' scenarios regarding future climate conditions.
- Economics data together with the published data [1] to re-evaluate the cost and benefits using more accurate data from local sources.

1. Data Description

Five types of primary and secondary data are described in the database as; climate data, soil data, suitability assessment, crop-related data and economic data. The following different sections describe relevant data types and their composition. It should be noted that the figures shown in this paper (Figs. 1–8) are for illustration purposes only. Individual data are available at the open repository (see data accessibility section above).

1.1. Climate data

The study was carried out in six locations in Malaysia; Alor Setar (AS), Cameron Highlands (CH), Kuala Terengganu (KT), Petaling Jaya (PJ), Senai (SN) and Temerloh (TM). The weather data collection sites, which were used as different locations in yield simulations are shown in Fig. 1. All the data were generated for the locations shown in Fig. 1.

The total rainfall and reference evapotranspiration (simulated) of 6 locations are shown in Fig. 2. It should be noted that the period between 1st August and 18th December was considered as the most suitable hemp cultivation period in Malaysia [1].

Other than the 6 locations, simulations were carried out across Peninsular Malaysia for the locations shown in Fig. 1. Fig. 3 shows the interpolated maps of rainfall and reference evapotranspiration of Malaysia. The raw files of the maps are all available in an open repository mentioned in the data accessibility section.

Since the yield simulation and economic assessments were performed in the future climates (2040–2065), the future rainfall and reference evapotranspiration data of the study locations are also available in the data repository. The files are available in Excel format.

1.2. Soil data

Infiltration (infiltrated water in soil profile), runoff (water lost by surface runoff) and drainage (water drained out of the soil profile) are three important soil data types that are important in agricultural water management. These parameters can be generated in AquaCrop simulations. The infiltration, runoff and drainage data of 6 study locations are available in Excel format. The summary statistics of the data are shown in Table 1.

1.3. Agroecological suitability data

To perform suitability analysis, variety of geospatial data was required. The following are description of codes for suitability files/data that was used to create suitability analysis:

Raw data that was used to create suitability maps:

10,001,002,500	CropID for hemp [8]
SRTM	SRTM data acquired from (Jarvis et al.) [14].
MYS	three-letter country abbreviation for Malaysia ISO-3166 Alpha-3 https://laendercode.net/en/3-letter-code/mys).
WC	WorldClim data version 2 [11]
SG	Soilgrids data [10]

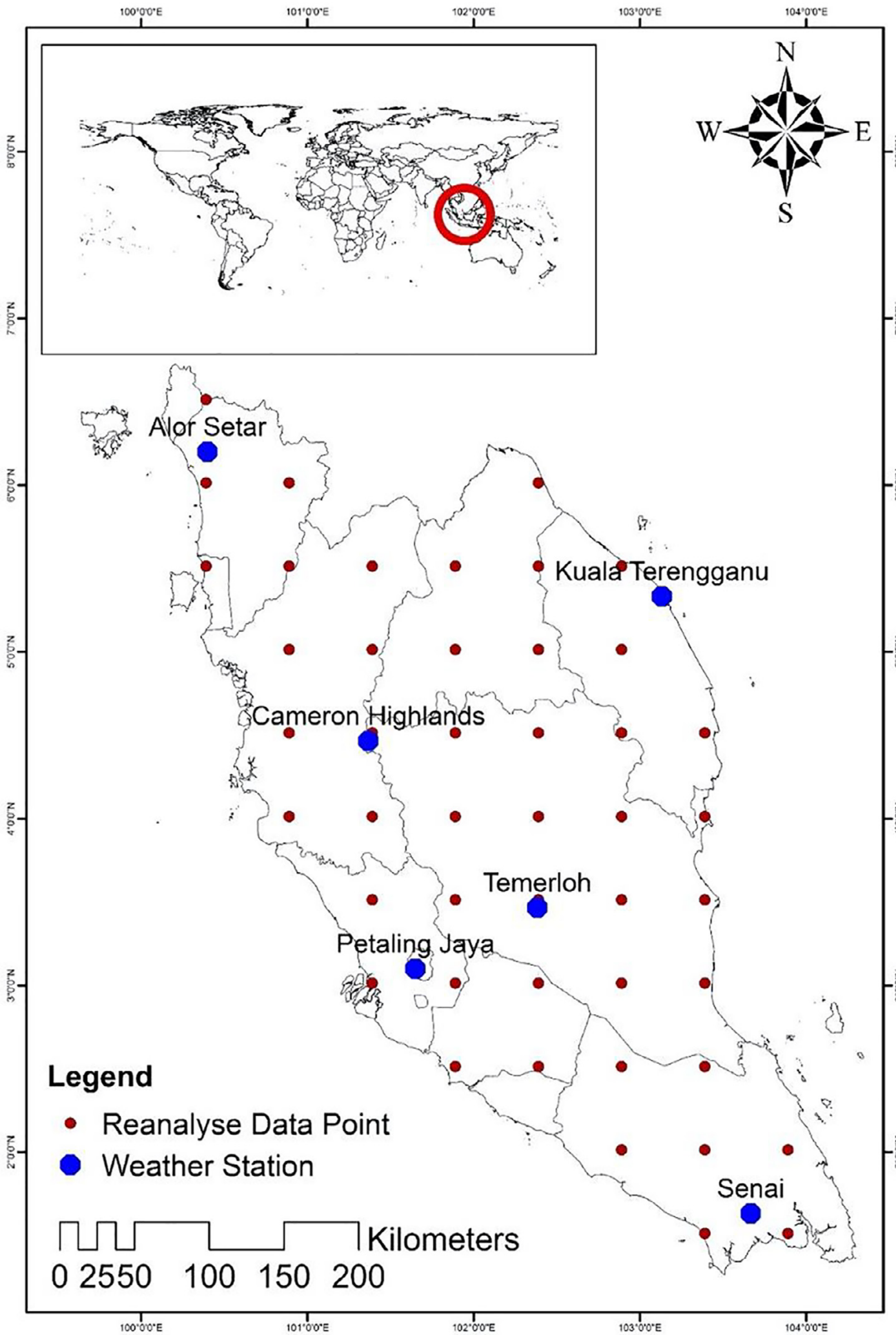

Fig. 1. Map of Peninsular Malaysia with locations used in yield simulations (adapted from Wimalasiri et al. [7,1]).

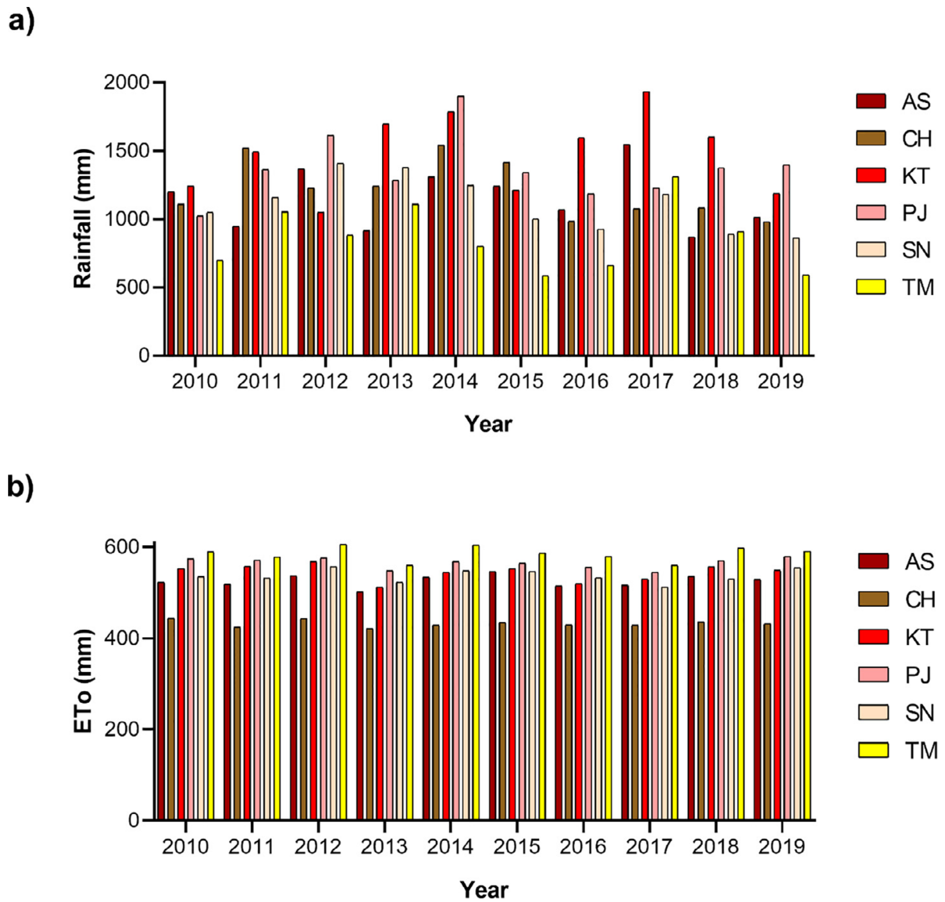

Fig. 2. Variation of growing seasonal (a) rainfall and (b) reference evapotranspiration of 6 locations studied. The locations marked as Alor Setar = AS, Cameron Highlands = CH, Kuala Terengganu = KT, Petaling Jaya = PJ, Senai = SN and Temerloh = TM.

Description of codes for processed files following the method by (Jahanshiri et al.) [2]:

TSM:	Seasonal Temperature Suitability	12 files
RSM:	Seasonal Rainfall Suitability	12 files
TCSM:	Product of Seasonal Climate and soil Suitability	12 files
ACSM:	Average of Seasonal Climate and soil suitability	12 files
MTCS:	Mean of total climate suitability for 12 months	1 file
MTS:	Maximum Temperature Suitability	1 file
MATSS:	Mean of soil suitability and Maximum Temperature suitability	1 file
pHS:	pH suitability	1 file
DTBS:	Depth suitability	1 file
TXTS:	Texture suitability	1 file
MTSS:	Weighted mean of soil layers (60% pH, 20% Depth, 20% texture)	1 file
Elev:	Elevation Suitability	1 file

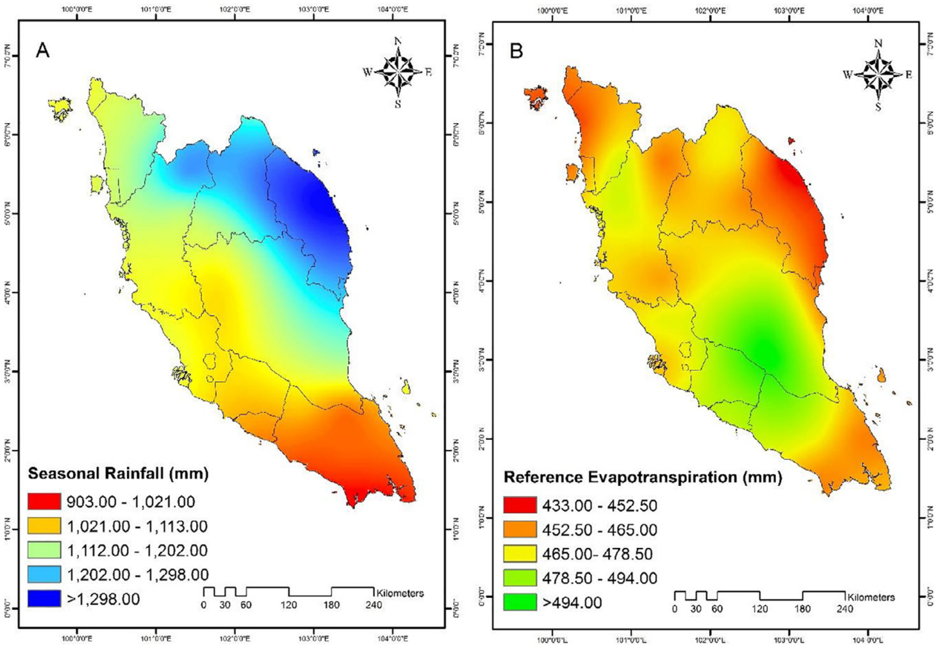

Fig. 3. Interpolated (A) growing seasonal rainfall and (B) reference evapotranspiration map of Malaysia (data available in the repository).

Table 1
Summary statistics of infiltration, runoff and drain data of the study locations in Malaysia.

Location	Parameter	Average	Standard deviation	Range
Alor Setar	Infiltration (mm)	905	134	723–1134
	Runoff (mm)	244	101	96–415
	Drain (mm)	198	115	61–420
Cameron Highlands	Infiltration (mm)	996	150	813–1236
	Runoff (mm)	223	64	147–344
	Drain (mm)	370	145	225–598
Kuala Terengannu	Infiltration (mm)	986	158	806–1184
	Runoff (mm)	495	215	223–936
	Drain (mm)	302	132	104–475
Petaling Jaya	Infiltration (mm)	1041	142	827–1341
	Runoff (mm)	331	109	197–560
	Drain (mm)	280	125	58–524
Senai	Infiltration (mm)	899	122	710–1073
	Runoff (mm)	212	80	129–345
	Drain (mm)	180	93	32–315
Temerloh	Infiltration (mm)	736	174	526–1074
	Runoff (mm)	125	72	63–238
	Drain (mm)	23	68	0–215

Standard metadata that was used to harmonize the primary data and generate output data:

Dimensions: 655, 589, 385,795, 6 (nrow, ncol, ncell, nlayers)
Resolution: 0.008333333, 0.008333333 (x, y) or approximately 1 km
Extent: 99.64167, 104.55, 1.266667, 6.725 (xmin, xmax, ymin, ymax)
Coordinate reference system: +proj=longlat +datum=WGS84 +no_defs +ellps=WGS84 +towgs84=0,0,0

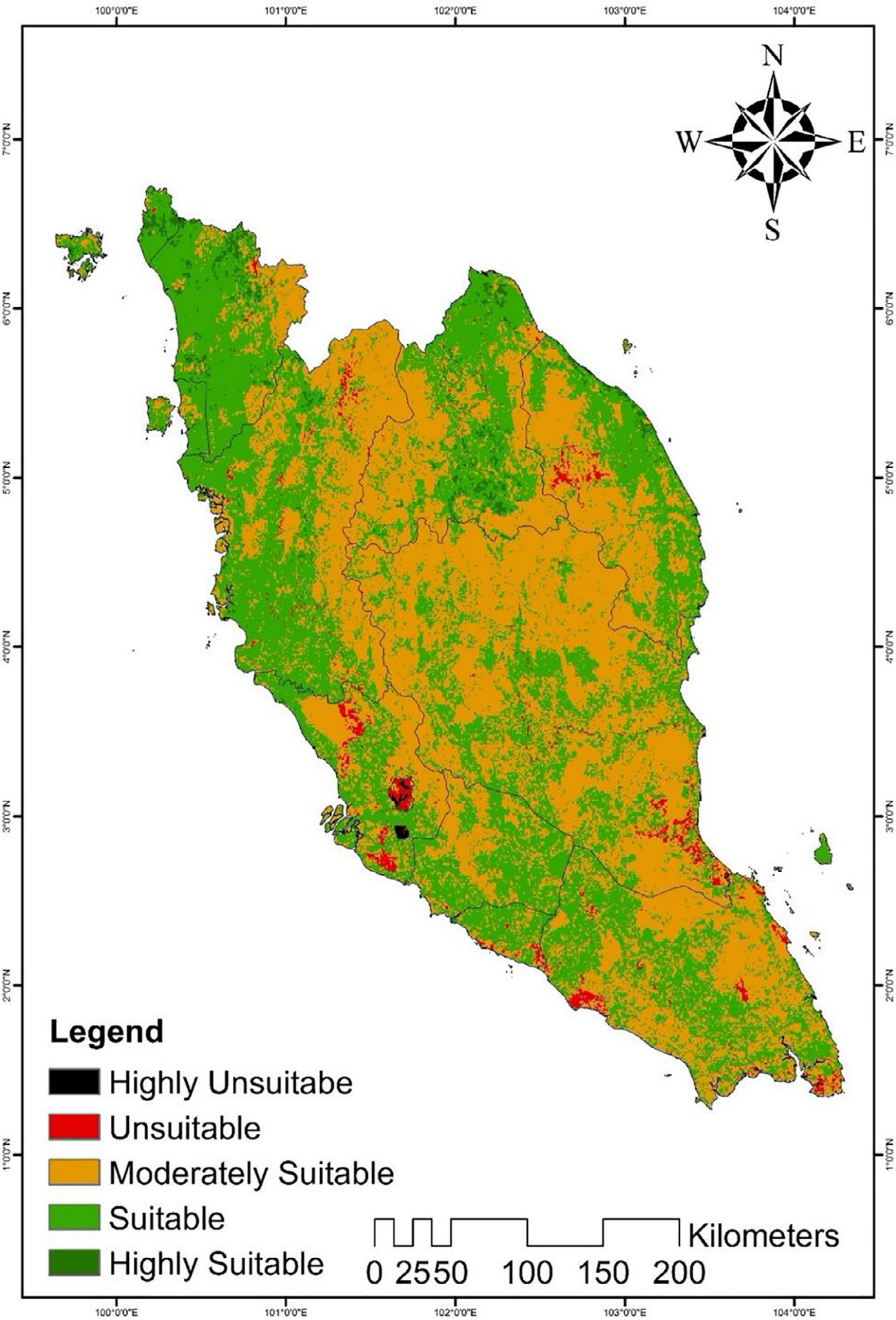

Fig. 4. Overall suitability map for hemp in Peninsular Malaysia (adapted from Wimalasiri et al. [7]) [1] (data available in the repository).

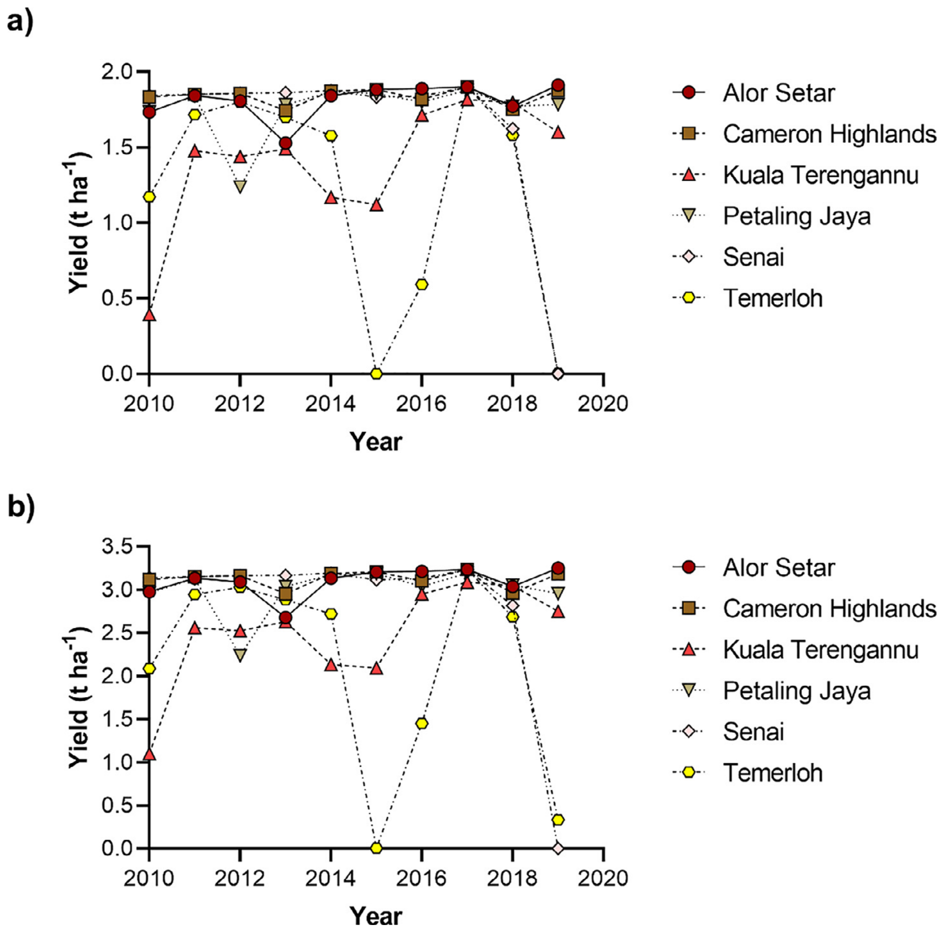

Fig. 5. Variation of simulated hemp seed and fiber yield of 6 locations in Malaysia.

1.4. Land suitability data

The overall suitability map of hemp for Malaysia is shown in Fig. 4 after contrasting with land-use classes using data from GlobeCover [13], a land suitability map was developed to aid with delineating suitable areas for planting hemp for both seed and fiber. This suitability map has been provided as GEOTIFF raster format to allow further analysis to be done at all levels.

1.5. Crop data

The simulated hemp seed and fiber yields of 6 locations under current climate (2010–2019 period) is available as Excel file. The hemp yield variation of 6 locations and summary statistics are shown in Fig. 5 and Table 2, respectively. Tools and procedures to develop the simulated seed and fiber yield were described in Section 2.3.

Table 2 shows the summary of hemp yield. The simulated range can be used to develop a confidence analysis for the performance of hemp in Malaysia or any other type of analysis that

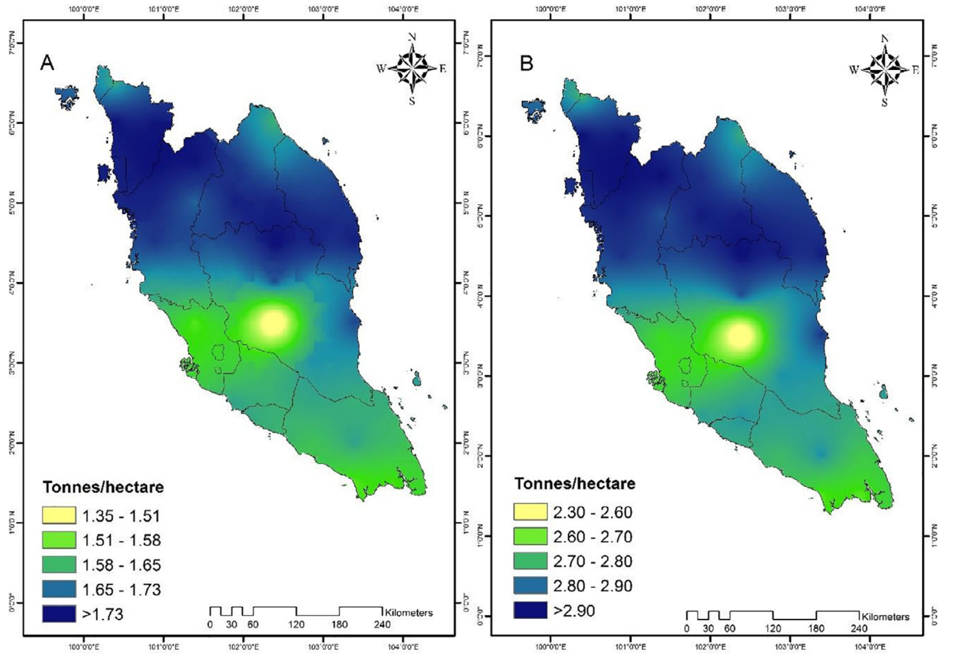

Fig. 6. Interpolated hemp (A) seed and (B) yield map of Malaysia (adapted from Wimalasiri et al. [7]) [1] (data available in the repository).

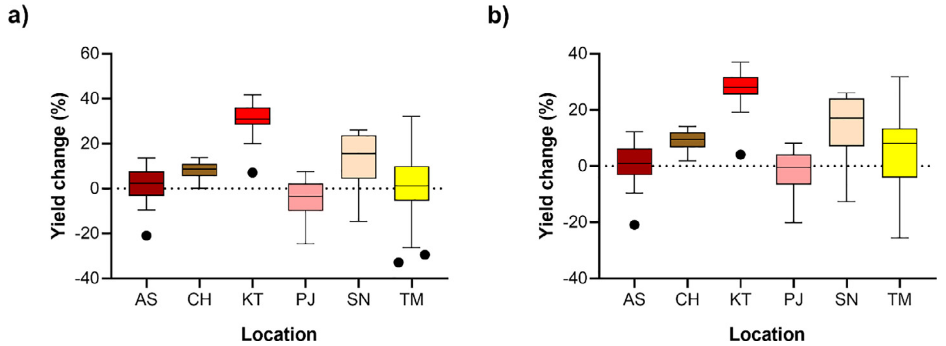

Fig. 7. Change of future (2040–2065) hemp (a) seed and (b) fiber yields compared to 2010–2019 period in Malaysia. The locations marked as Alor Setar = AS, Cameron Highlands = CH, Kuala Terengganu = KT, Petaling Jaya = PJ, Senai = SN and Temerloh = TM.

Table 2
Summary statistics of hemp seed and fiber yield during 2010–2019 period.

	Seed		Fiber	
Location	Mean and SD	Range	Mean and SD	Range
Alor setar	1.81 ± 0.11	1.53–1.91	3.10 ± 0.17	2.68–3.25
Cameron highlands	1.84 ± 0.05	1.74–1.90	3.13 ± 0.10	2.95–3.24
Kuala terengannu	1.40 ± 0.43	0.39–1.82	2.49 ± 0.59	1.10–3.09
Petaling jaya	1.76 ± 0.19	1.24–1.88	3.00 ± 0.28	2.24–3.19
Senai	1.65 ± 0.58	0.00–1.90	2.81 ± 0.99	0.001–3.23
Temerloh	1.21 ± 0.74	0.001–1.90	2.14 ± 1.16	0.005–3.24

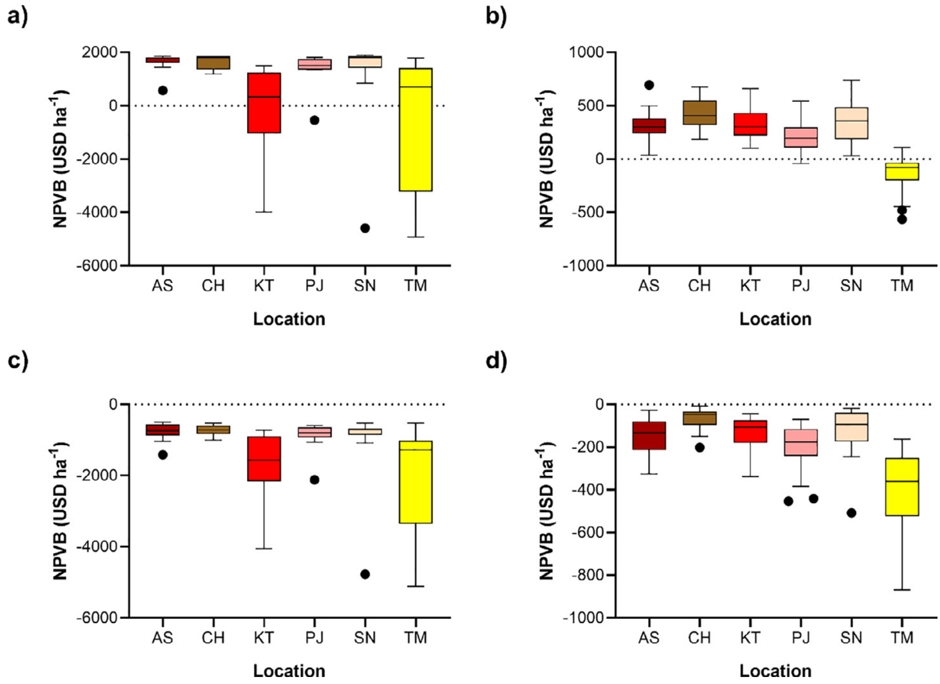

Fig. 8. The NPVB values for hemp seed (a and b) and fiber (c and d) during 2010–2019 (a and c) and 2040–2065 (b and d) period. The locations marked as Alor Setar = AS, Cameron Highlands = CH, Kuala Terengganu = KT, Petaling Jaya = PJ, Senai = SN and Temerloh = TM.

require quantitative values of hemp yield in Malaysia and other possible areas with similar agro-ecological characteristics.

Potential yield maps for seed and fiber for the 1990–2019 period for Malaysia were created (Fig. 6). As crop physiological data, temperature stress affecting crop transpiration (TempStr), leaf expansion stress (ExpStr), stomatal stress (StoStr) and evapotranspiration water productivity for yield part (kg yield produced per m^3 water evapotranspired (WPet) are provided in the data repository as Excel files. This data can be readily used for any other type of analysis involving hydrological processes across peninsular Malaysia.

Simulated hemp seed and fiber yield under future climate (2040–2065) are available as Excel files. As a use case for the data, Fig. 7 shows the percentage yield change under future climate, compared to the 2010–2019 period.

1.6. Economic data

The cost benefit analysis data of hemp seed and fiber under both current (2010–2019) and future (2040–2069) climates are included in the dataset as Excel files. The Summary of the economic analysis data for hemp seed and fiber production is shown in Fig. 8.

2. Experimental Design, Materials and Methods

Detailed methodology of the generation of the database was previously described by Wimalasiri et al. [7]. Therefore, only a summary is presented here. The process flow chart of the generation of data is shown in Fig. 9.

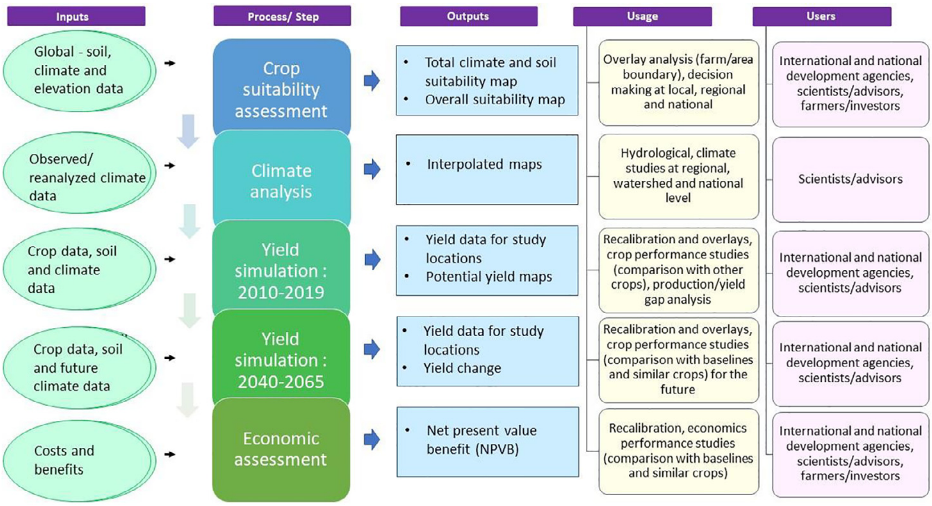

Fig. 9. Flow chart showing input and output data, their usage and possible users for such data.

2.1. Data collection

2.1.1. Climate data

Observed daily climate data for 2010–2019 period were collected for 6 meteorological locations (Fig. 1) from the Meteorological Department of Malaysia. This included daily rainfall and minimum and maximum temperatures. Reanalysis daily climate data (rainfall, temperature and solar radiation) for 1990–2019 period were collected from NASA POWER database, described by Zhang et al. [15]. The data are available at 0.5-degree resolution which created 46 different climate files. The WorldClim dataset [11] was used in the climate suitability assessment. Bias-corrected daily climate data for 2040–2065 period were obtained from the (CCAFS) database (http://ccafs-climate.org/) for future simulations. The data were downscaled for 5 GCMs; BNU_ESM of College of Global Change and Earth System Science, Beijing Normal University, China, CNRM_CM5 of center National de Recherches Meteorologiques/center Europeen de Recherche et Formation Avancees en Calcul Scientifique, Italy, MIROC_ESM from Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute, and National Institute for Environmental Studies, Japan, MOHC_HadGEM2_CC from Met-Office Hadley center, United Kingdom and NCC_NorESM1_M of Norwegian Climate center, Norway.

2.1.2. Soil data

Soil data were collected from the Soilgrids 2.0 database (www.soilgrids.org). The database was previously used in crop modeling studies [16].

2.2. Crop suitability assessment

The climate and soil suitability of hemp in Malaysia was performed using the land evaluation framework for agricultural diversification which previously developed by Jahanshiri et al. [2]. Climate data (temperature and rainfall) and soil data (pH and texture) were masked and then harmonised for peninsular Malaysia. The following steps were used to create the final suitability analysis:

1- Estimate a typical season length in months for hemp based on data from [8]

2- For each pixel on the map estimate 12 seasonal temperature suitability (12 starting months) by calculating suitability for each month within the season (step 1) against the temperature data [11]. Choose the minimum temperature suitability among all months as the representative temperature suitability for that season.
3- For each pixel in the map, estimate 12 seasonal rainfall suitability by accumulating monthly rainfall [11] for each season (step 1) and contrast with the total seasonal water requirement.
4- Identify the climate suitability as the highest suitable season for hemp.
5- Estimate soil pH and texture soil suitability by contrasting the soil data [10] at each pixel with the pH and texture requirement for hemp [1,2].
6- The total hemp suitability is the average of climate suitability and soil suitability for each pixel. This will create a map of suitability for hemp as shown in Fig. 4.

The final suitability layers (see Section 1.2 for the description of GeoTIFF files format) were average climate suitability, weighted average of soil suitability, average of climate and soil suitability and average of climate product of climate and soil suitability. Raw files for crop suitability were developed using R statistical software [3–5].

2.3. Yield simulation

The AquaCrop model [17] was used for hemp yield simulations. The calibration and validation of the model was described in a separated method paper [7]. The input parameters for the hemp grain and fiber crop in AquaCrop model was described in Wimalasiri et al. [1], therefore, the parameters were not included into the dataset described in this paper. Fiber yield was calculated manually [1]. Reference evapotranspiration data (Excel files) and their maps (GeoTIFF) and yield maps (GeoTIFF) were generated using the data derived from the yield simulation.

2.4. Mapping

The maps were generated using ArcGIS software version 10.6 (ESRI, Munich, Germany) using the 46 locations. The ordinary kriging was used as the interpolation method (Figs. 3 and 6).

2.5. Economic analysis

In the detailed economic analysis, Future Values (FV), Present Values (PV) and Net Present Value Benefit (NPVB) in relation to the Cost-Benefit (CB) approach were calculated and the data are available as Excel files (Section 1.6). The FV is corresponded to the total amount of money which will ensue over the period of investment that is calculated separately for all the years concerned. The PV is the current value of money resulted from investment of future over a period of time. The equations are as follows [18].

$$FV = \sum (Quantity\ of\ the\ item\ x\ Market\ value\ of\ the\ item)$$

$$PV = \frac{FV}{(1+r)^n}$$

where r is the discount rate or lending interest rate (4.9% in 2019 is used in the analysis for period of 2019–2065) and n is the year. For the period of 2010–2019, past values which is similar to the FVs in CB approach were converted to PVs by Malaysia Consumer Prices Index inflation calculator since the base year is 2019. NPVB was used to describe the benefits for each year which is similar to the net cash flow. The NPVB was calculated as follows.

$$\text{NPVB} = \text{Present Value Benefit of the } t\text{th year} - \text{Present Value Cost of the } t\text{th year}$$

where t is any year in the period of consideration.

3. Data and Stakeholders

As one of the important sectors in Malaysia, agriculture needs viable future-proof options to ensure its sustainability. Crop diversification can be a major source of innovation in Malaysia and elsewhere [19,20]. In particular, Malaysia should invest in new industrial crops apart from oil palm and rubber that can ensure income sustainability in the future, particularly for marginal areas and indigenous people [20]. This need has been reflected in the national agro-food policy in Malaysia which is also one of the pillars of United Nations Sustainability Goals. In this regard, presently published data can play an important part in the development of hemp as a potential industrial crop in Malaysia. Fig. 9 lists primary, secondary as well as published data, their application and possible stakeholders.

Ethics Statement

There is no conflict of interest. The data is available in public domain.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT Author Statement

Eranga M. Wimalasiri: Conceptualization, Methodology, Software, Formal analysis, Writing – original draft, Visualization; **Ebrahim Jahanshiri:** Conceptualization, Methodology, Software, Formal analysis, Writing – original draft; **Tengku Adhwa Syaherah:** Methodology, Software, Visualization; **Niluka Kuruppuarachchi:** Methodology, Formal analysis; **Vimbayi G.P. Chimonyo:** Methodology, Software, Validation; **Sayed N. Azam-Ali:** Writing – review & editing; **Peter J. Gregory:** Writing – review & editing.

Acknowledgments

The authors gratefully acknowledge Dr Francesco Danuso from University of Udine, Italy and Dr Kailei Tang from Wageningen University and Research, Netherlands, who shared their observed weather data with us to parameterise the crop model. We also acknowledge Anil Shekar Tharmandram, S.S. Mohd Sinin, N. M. Mohd Nizar and Nurul Jannah Abdullah of Crops For the Future Research center, Malaysia for their support.

Funding

This research was funded by European Union's Horizon 2020 research and innovation program, grant agreement No. 774234.

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