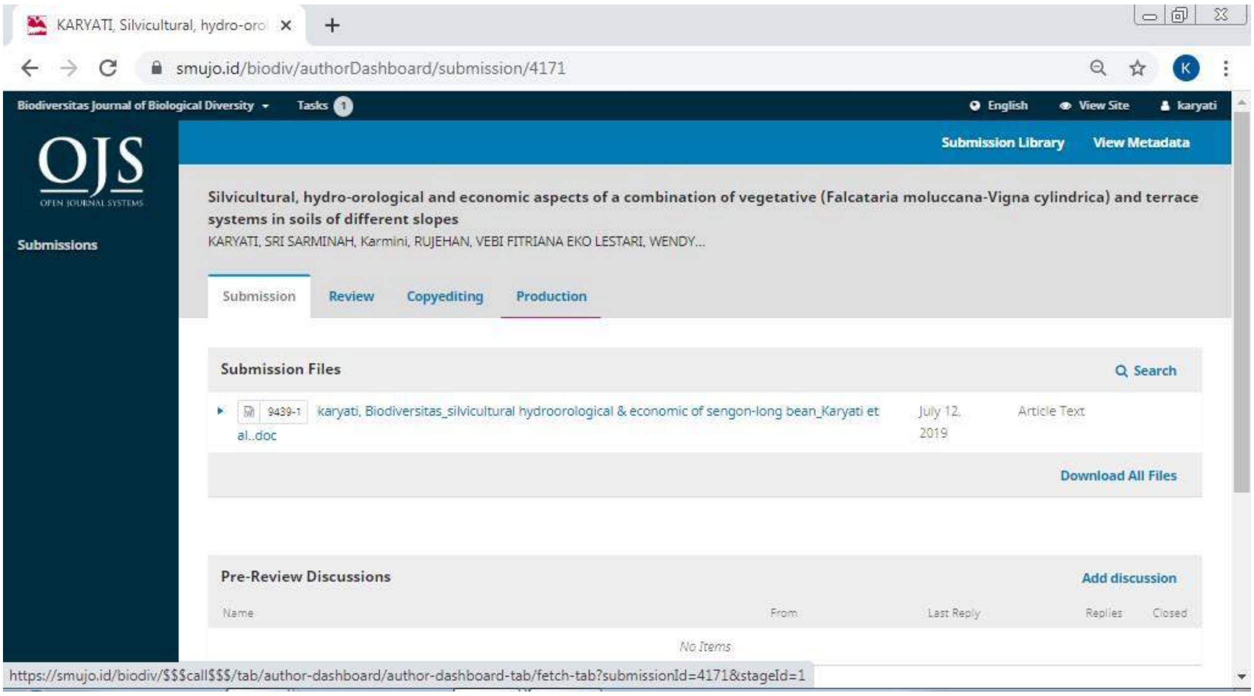
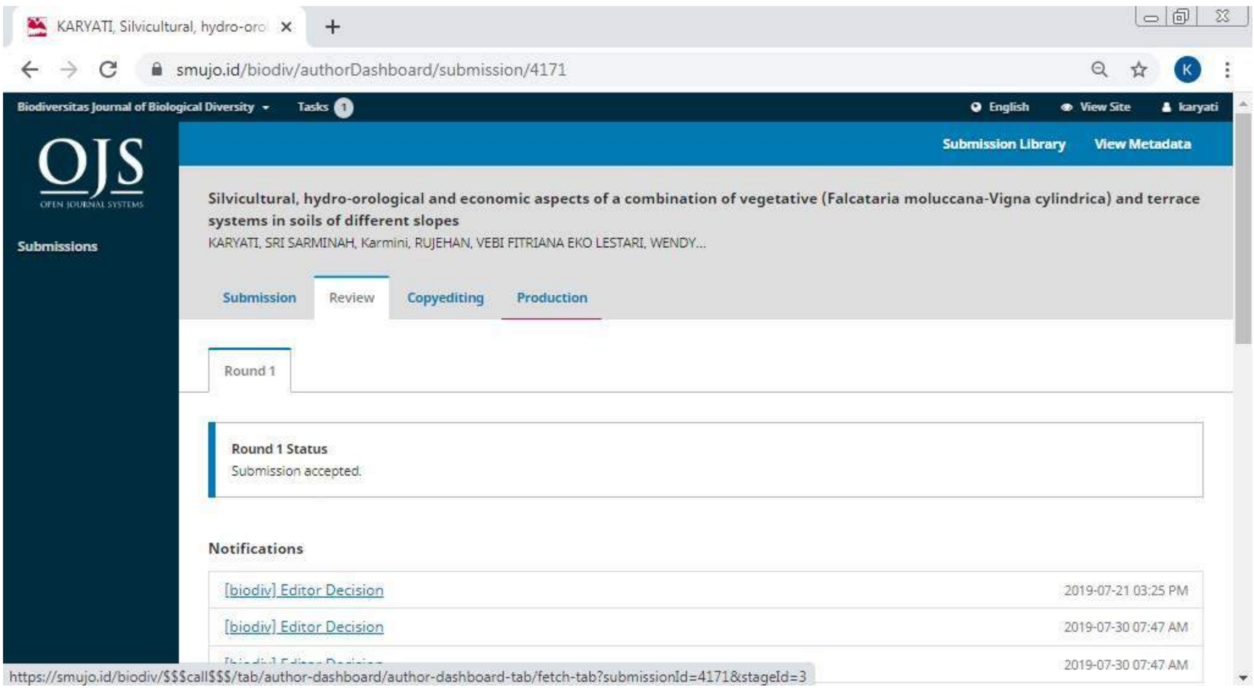
BUKTI-BUKTI PROSES REVIEW (KORESPONDENSI)

Judul	:	Silvicultural, Hydro-orological and Economic Aspects of a Combination of Vegetative (*Falcataria moluccana-Vigna cylindrica*) and Terrace Systems in Soils of Different Slopes
Penulis	:	Karyati, Sri Sarminah, Karmini, Rujehan, Vebi Fitriana Eko Lestari, dan Wendy Satria Panorama
Nama Jurnal	:	Biodiversitas
Volume/Nomor/Tahun/Halaman	:	20, 8, 2019, 2308-2315
ISSN	:	1412-033X/E-ISSN: 2085-4722
Penerbit	:	Society for Indonesian Biodiversity
DOI	:	10.13057/biodiv/d200828





KARYATI, Silvicultural, hydro-oro ×

smujo.id/biodiv/authorDashboard/submission/4171

Biodiversitas Journal of Biological Diversity Tasks 1 English View Site karyati

Reviewer's Attachments Search

9668-1	, 4171-Article Text-9459-1-4-20190714.doc	July 21, 2019

Revisions Search Upload File

No Files

Review Discussions Add discussion

Name	From	Last Reply	Replies	Closed
Uncorrected Proof	editors 2019-07-23 02:41 AM	-	0	
BILLING	dewinurpratiwi 2019-07-23 05:42 AM	-	0	

KARYATI, Silvicultural, hydro-oro ×

smujo.id/biodiv/authorDashboard/submission/4171

Biodiversitas Journal of Biological Diversity Tasks 1 English View Site karyati

OJS OPEN JOURNAL SYSTEMS

Submissions

Submission Library View Metadata

Silvicultural, hydro-orological and economic aspects of a combination of vegetative (Falcataria moluccana-Vigna cylindrica) and terrace systems in soils of different slopes

KARYATI, SRI SARMINAH, Karmini, RUJEHAN, VEBI FITRIANA EKO LESTARI, ...

Submission Review Copyediting Production

Copyediting Discussions Add discussion

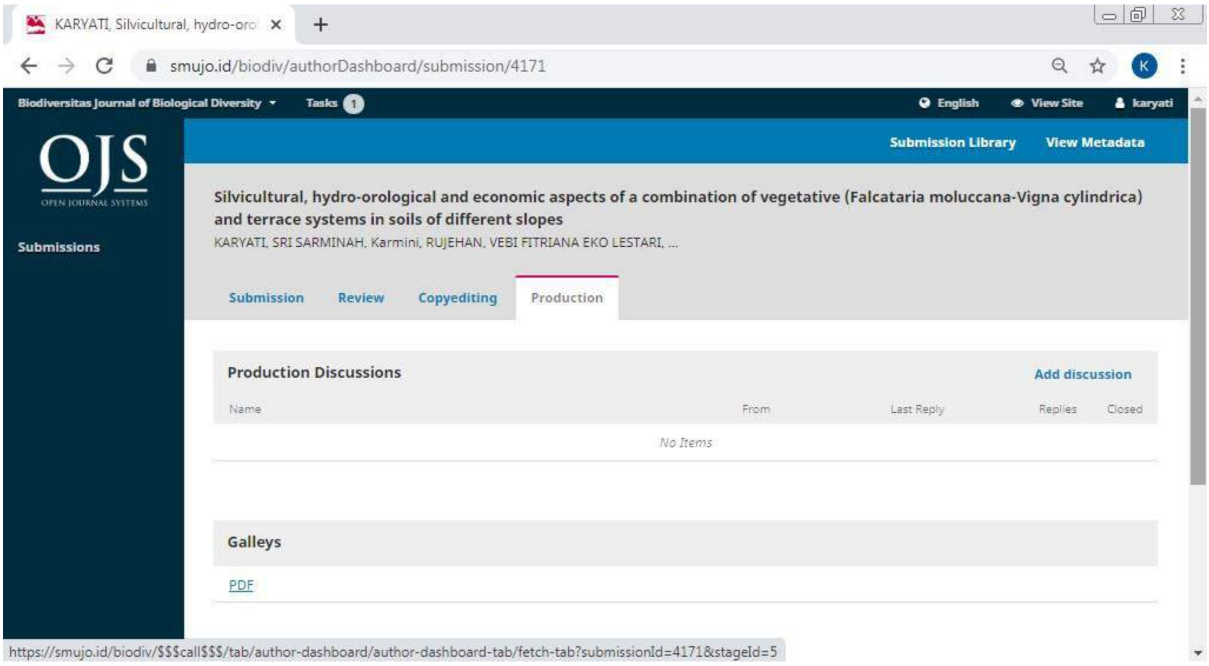
Name	From	Last Reply	Replies	Closed

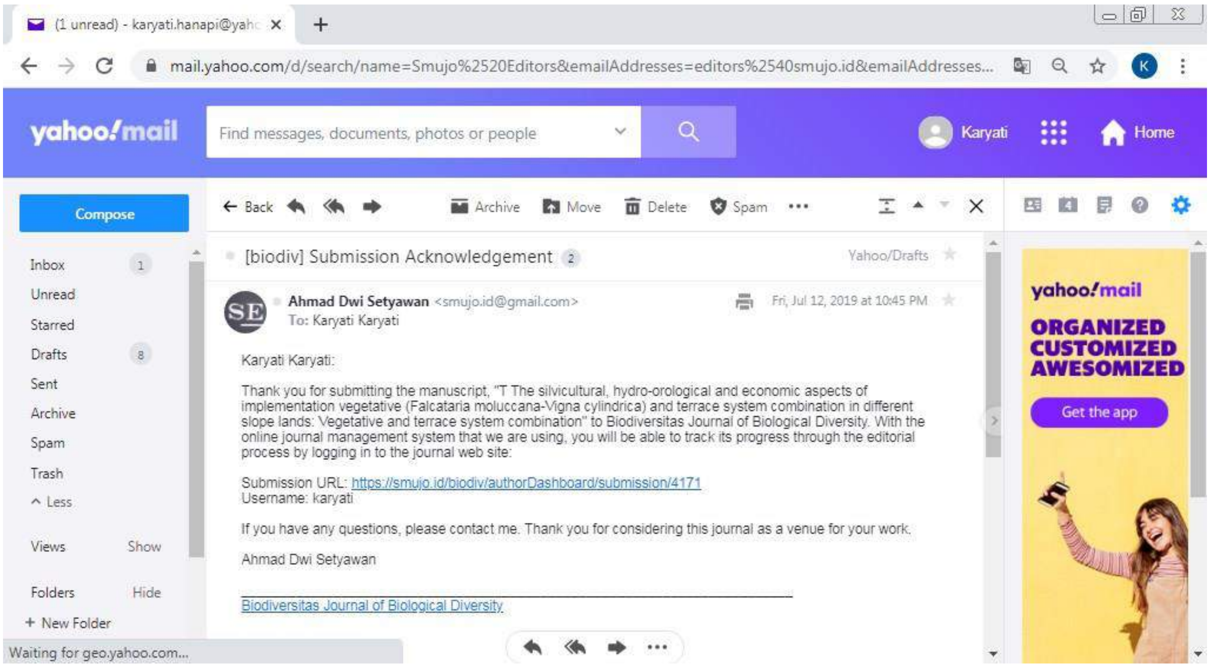
No Items

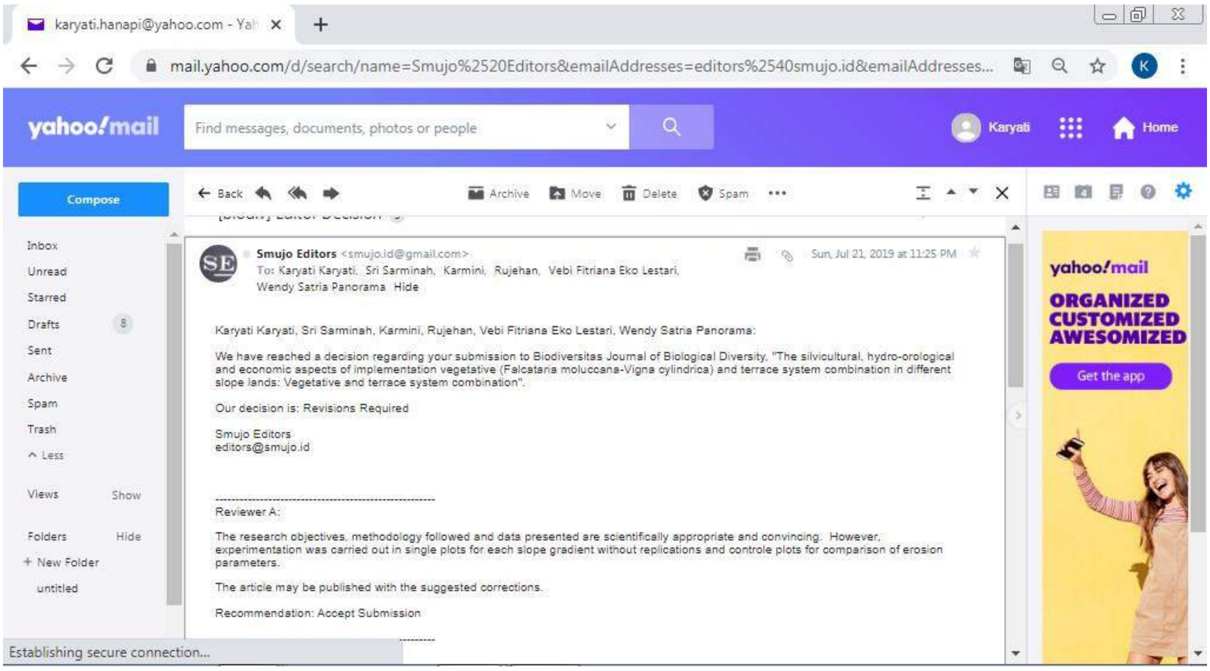
Copyedited Search

9935-1	editors, D200828-Falcataria moluccana-Vigna cylindrica+rev[02]_KK.edited.docx	July 30, 2019	Article Text

https://smujo.id/biodiv/$$$call$$$/tab/author-dashboard/author-dashboard-tab/fetch-tab?submissionId=4171&stageId=4


KARYATI, Silvicultural, hydro-oro
smujo.id/biodiv/authorDashboard/submission/4171
Biodiversitas Journal of Biological Diversity
Tasks 1
English
View Site
karyati
OJS
OPEN JOURNAL SYSTEMS
Submissions
Submission Library
View Metadata
Silvicultural, hydro-orological and economic aspects of a combination of vegetative (Falcataria moluccana-Vigna cylindrica) and terrace systems in soils of different slopes
KARYATI, SRI SARMINAH, Karmini, RUJEHAN, VEBI FITRIANA EKO LESTARI, ...
Submission
Review
Copyediting
Production
Production Discussions
Add discussion
Name
From
Last Reply
Replies
Closed
No Items
Galleys
PDF
https://smujo.id/biodiv/$$$call$$$/tab/author-dashboard/author-dashboard-tab/fetch-tab?submissionId=4171&stageId=5


(1 unread) - karyati.hanapi@yah
mail.yahoo.com/d/search/name=Smujo%2520Editors&emailAddresses=editors%2540smujo.id&emailAddresses...
yahoo!mail
Find messages, documents, photos or people
Karyati
Home
Compose
Back
Archive
Move
Delete
Spam
Inbox 1
Unread
Starred
Drafts 8
Sent
Archive
Spam
Trash
Less
Views Show
Folders Hide
+ New Folder
[biodiv] Submission Acknowledgement 2
Yahoo/Drafts
Ahmad Dwi Setyawan <smujo.id@gmail.com>
To: Karyati Karyati
Fri, Jul 12, 2019 at 10:45 PM
Karyati Karyati:
Thank you for submitting the manuscript, "T The silvicultural, hydro-orological and economic aspects of implementation vegetative (Falcataria moluccana-Vigna cylindrica) and terrace system combination in different slope lands: Vegetative and terrace system combination" to Biodiversitas Journal of Biological Diversity. With the online journal management system that we are using, you will be able to track its progress through the editorial process by logging in to the journal web site:
Submission URL: https://smujo.id/biodiv/authorDashboard/submission/4171
Username: karyati
If you have any questions, please contact me. Thank you for considering this journal as a venue for your work.
Ahmad Dwi Setyawan
Biodiversitas Journal of Biological Diversity
yahoo!mail
ORGANIZED
CUSTOMIZED
AWESOMIZED
Get the app
Waiting for geo.yahoo.com...



Smujo Editors <smujo.id@gmail.com> Sun, Jul 21, 2019 at 11:25 PM

To: Karyati Karyati, Sri Sarminah, Karmini, Rujehan, Vebi Fitriana Eko Lestari, Wendy Satria Panorama

Karyati Karyati, Sri Sarminah, Karmini, Rujehan, Vebi Fitriana Eko Lestari, Wendy Satria Panorama:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "The silvicultural, hydro-orological and economic aspects of implementation vegetative (Falcataria moluccana-Vigna cylindrica) and terrace system combination in different slope lands: Vegetative and terrace system combination".

Our decision is: Revisions Required

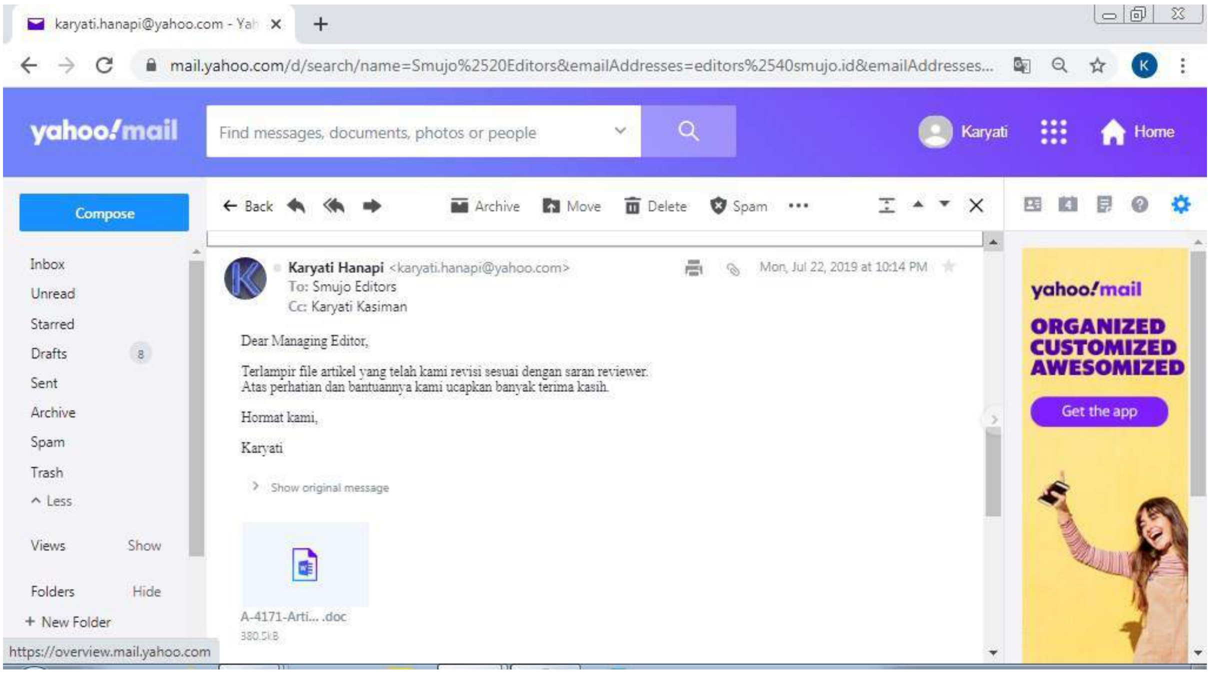
Smujo Editors
editors@smujo.id

Reviewer A:

The research objectives, methodology followed and data presented are scientifically appropriate and convincing. However, experimentation was carried out in single plots for each slope gradient without replications and controle plots for comparison of erosion parameters.

The article may be published with the suggested corrections.

Recommendation: Accept Submission



Karyati Hanapi <karyati.hanapi@yahoo.com> Mon, Jul 22, 2019 at 10:14 PM

To: Smujo Editors
Cc: Karyati Kasiman

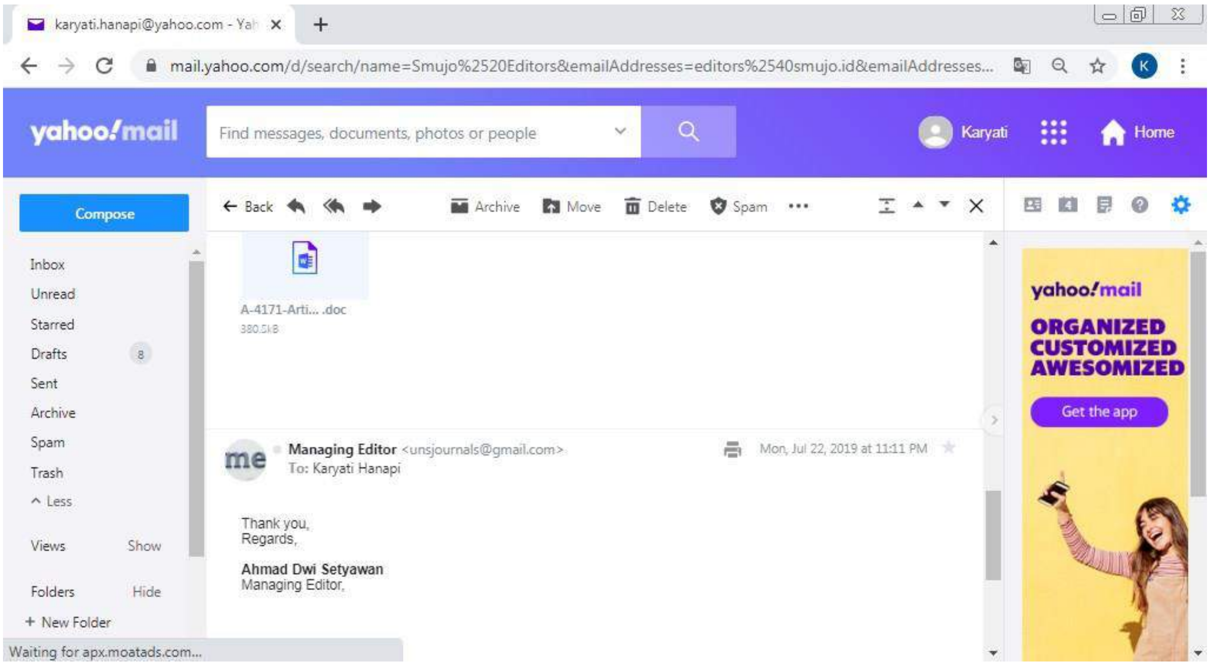
Dear Managing Editor,

Terlampir file artikel yang telah kami revisi sesuai dengan saran reviewer.
Atas perhatian dan bantuannya kami ucapkan banyak terima kasih.

Hormat kami,

Karyati

A-4171-Arti... .doc
380.5kB



karyati.hanapi@yahoo.com - Yah

mail.yahoo.com/d/search/name=Smujo%2520Editors&emailAddresses=editors%2540smujo.id&emailAddresses...

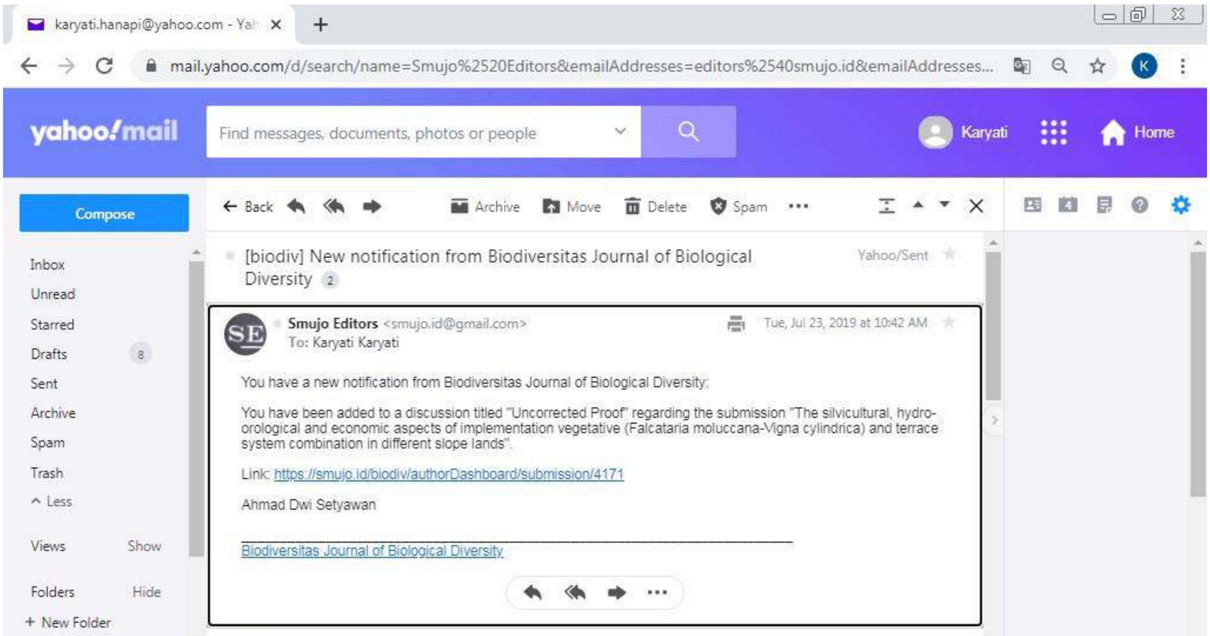
A-4171-Arti... .doc

Managing Editor <unsjournals@gmail.com> Mon, Jul 22, 2019 at 11:11 PM

To: Karyati Hanapi

Thank you,
Regards,

Ahmad Dwi Setyawan
Managing Editor,



karyati.hanapi@yahoo.com - Yah

mail.yahoo.com/d/search/name=Smujo%2520Editors&emailAddresses=editors%2540smujo.id&emailAddresses...

[biodiv] New notification from Biodiversitas Journal of Biological Diversity 2 Yahoo/Sent

Smujo Editors <smujo.id@gmail.com> Tue, Jul 23, 2019 at 10:42 AM

To: Karyati Karyati

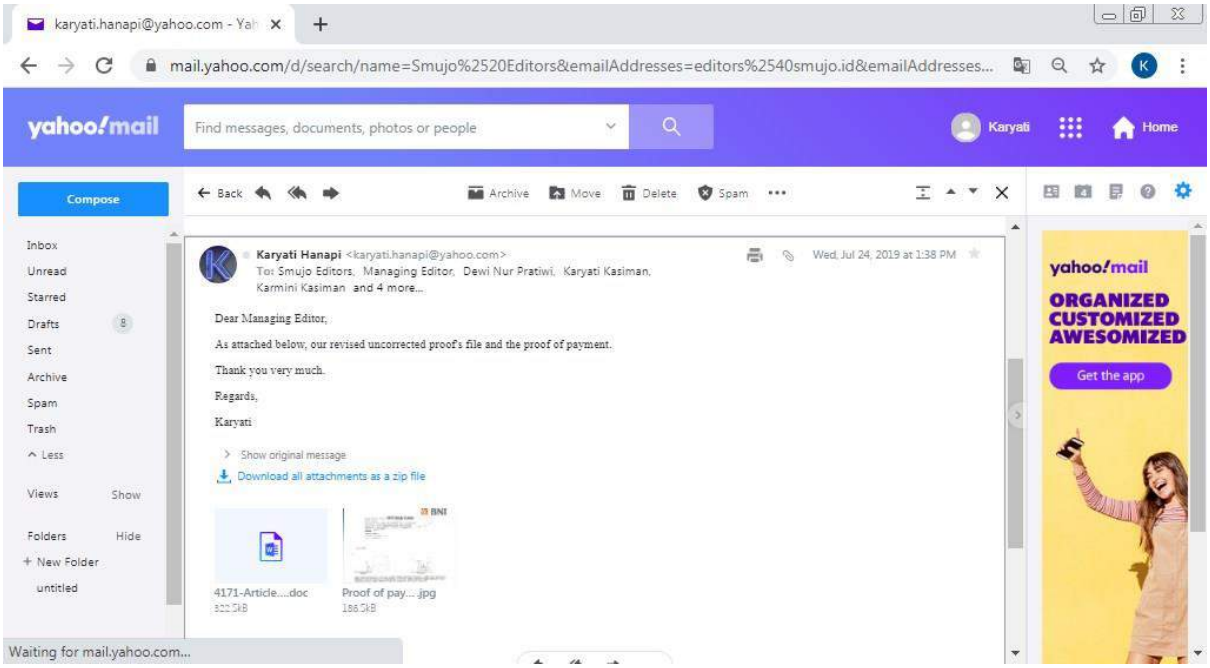
You have a new notification from Biodiversitas Journal of Biological Diversity:

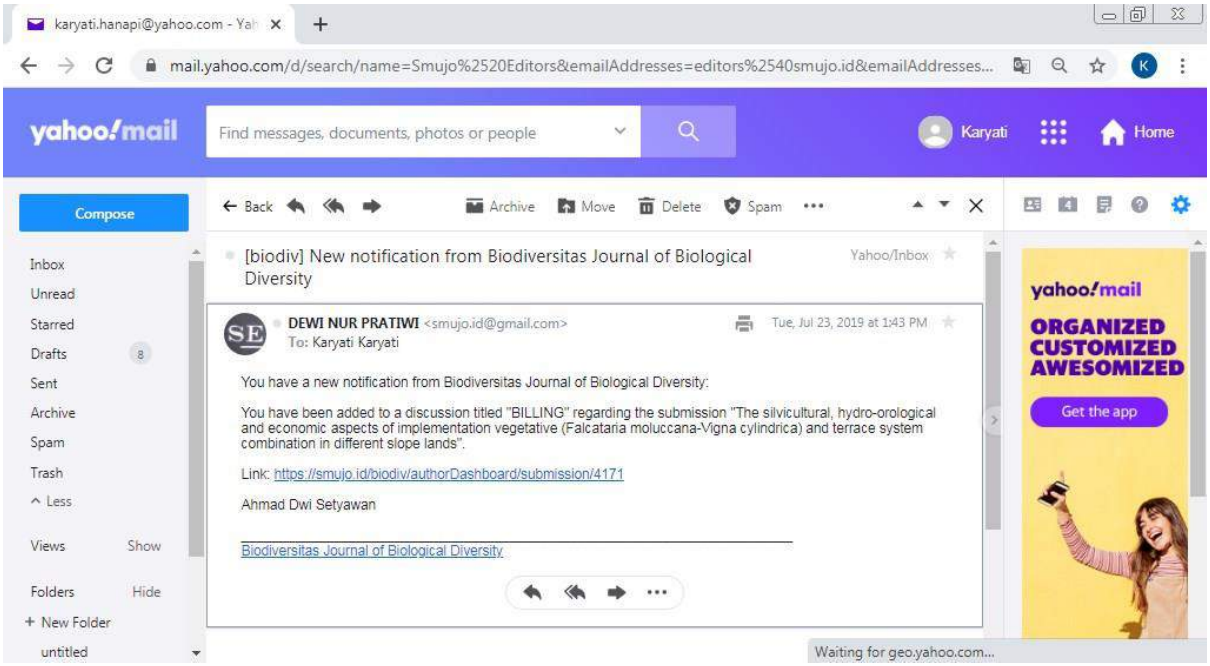
You have been added to a discussion titled "Uncorrected Proof" regarding the submission "The silvicultural, hydro-orological and economic aspects of implementation vegetative (Falcataria moluccana-Vigna cylindrica) and terrace system combination in different slope lands".

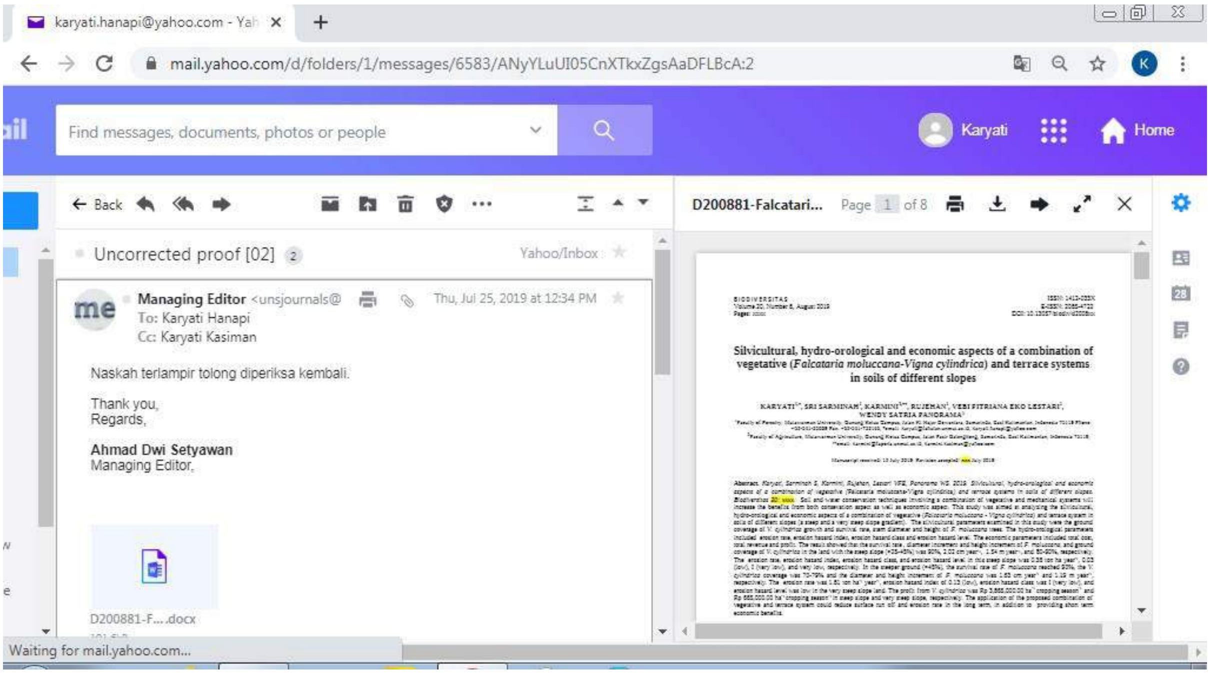
Link: https://smujo.id/biodiv/authorDashboard/submission/4171

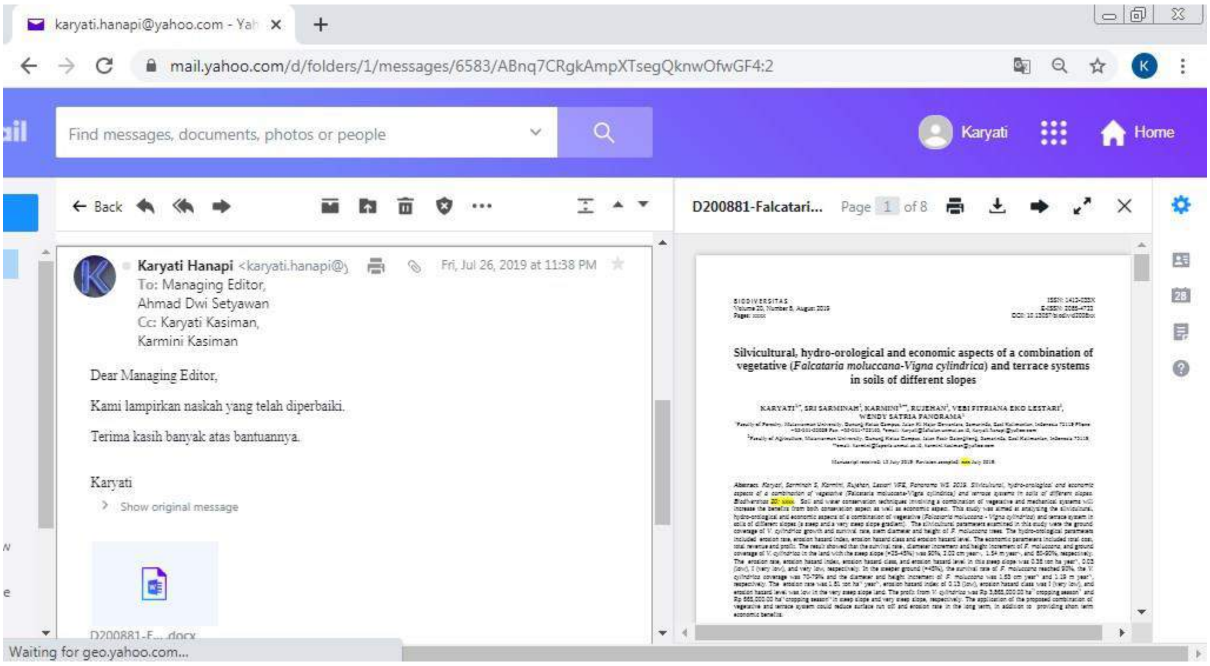
Ahmad Dwi Setyawan

Biodiversitas Journal of Biological Diversity


karyati.hanapi@yahoo.com - Yah
mail.yahoo.com/d/search/name=Smujo%2520Editors&emailAddresses=editors%2540smujo.id&emailAddresses...
yahoo!mail
Find messages, documents, photos or people
Karyati
Home
Compose
Back
Archive
Move
Delete
Spam
Inbox
Unread
Starred
Drafts
Sent
Archive
Spam
Trash
Less
Views
Show
Folders
Hide
+ New Folder
untitled
Karyati Hanapi <karyati.hanapi@yahoo.com>
To: Smujo Editors, Managing Editor, Dewi Nur Pratiwi, Karyati Kasiman, Karmini Kasiman and 4 more...
Wed, Jul 24, 2019 at 1:38 PM
Dear Managing Editor,
As attached below, our revised uncorrected proof's file and the proof of payment.
Thank you very much.
Regards,
Karyati
Show original message
Download all attachments as a zip file
4171-Article....doc
Proof of pay....jpg
186.5kB
yahoo!mail
ORGANIZED
CUSTOMIZED
AWESOMIZED
Get the app
Waiting for mail.yahoo.com...


karyati.hanapi@yahoo.com - Yah
mail.yahoo.com/d/search/name=Smujo%2520Editors&emailAddresses=editors%2540smujo.id&emailAddresses...
yahoo!mail
Find messages, documents, photos or people
Karyati
Home
Compose
Back
Archive
Move
Delete
Spam
Inbox
Unread
Starred
Drafts
Sent
Archive
Spam
Trash
Less
Views
Show
Folders
Hide
+ New Folder
untitled
[biodiv] New notification from Biodiversitas Journal of Biological Diversity
Yahoo/Inbox
DEWI NUR PRATIWI <smujo.id@gmail.com>
To: Karyati Karyati
Tue, Jul 23, 2019 at 1:43 PM
You have a new notification from Biodiversitas Journal of Biological Diversity:
You have been added to a discussion titled "BILLING" regarding the submission "The silvicultural, hydro-orological and economic aspects of implementation vegetative (Falcataria moluccana-Vigna cylindrica) and terrace system combination in different slope lands".
Link: https://smujo.id/biodiv/authorDashboard/submission/4171
Ahmad Dwi Setyawan
Biodiversitas Journal of Biological Diversity
yahoo!mail
ORGANIZED
CUSTOMIZED
AWESOMIZED
Get the app
Waiting for geo.yahoo.com...


karyati.hanapi@yahoo.com - Yah
mail.yahoo.com/d/folders/1/messages/6583/ANyYLuUI05CnXTkxZgsAaDFLBcA:2
Find messages, documents, photos or people
Karyati
Home
Back
D200881-Falcatari...
Page 1 of 8
Uncorrected proof [02]
Yahoo/Inbox
Managing Editor <unsjournals@
Thu, Jul 25, 2019 at 12:34 PM
To: Karyati Hanapi
Cc: Karyati Kasiman
Naskah terlampir tolong diperiksa kembali.
Thank you,
Regards,
Ahmad Dwi Setyawan
Managing Editor,
D200881-F....docx
Silvicultural, hydro-orological and economic aspects of a combination of vegetative (Falcataria moluccana-Vigna cylindrica) and terrace systems in soils of different slopes
Waiting for mail.yahoo.com...


karyati.hanapi@yahoo.com - Yah
mail.yahoo.com/d/folders/1/messages/6583/ABnq7CRgkAmpXTsegQknwOfwGF4:2
Find messages, documents, photos or people
Karyati
Home
Back
D200881-Falcatari...
Page 1 of 8
Karyati Hanapi <karyati.hanapi@y
Fri, Jul 26, 2019 at 11:38 PM
To: Managing Editor,
Ahmad Dwi Setyawan
Cc: Karyati Kasiman,
Karmini Kasiman
Dear Managing Editor,
Kami lampirkan naskah yang telah diperbaiki.
Terima kasih banyak atas bantuannya.
Karyati
Show original message
D200881-F....docx
Silvicultural, hydro-orological and economic aspects of a combination of vegetative (Falcataria moluccana-Vigna cylindrica) and terrace systems in soils of different slopes
Waiting for geo.yahoo.com...

karyati.hanapi@yahoo.com - Yah

mail.yahoo.com/d/search/name=Smujo%2520Editors&emailAddresses=editors%2540smujo.id&emailAddresses...

[biodiv] Editor Decision

Smujo Editors <smujo.id@gmail.com> Tue, Jul 30, 2019 at 3:47 PM

To: KARYATI, SRI SARMINAH, Karmini, RUJEHAN, VEBI FITRIANA EKO LESTARI and 1 more...

KARYATI, SRI SARMINAH, Karmini, RUJEHAN, VEBI FITRIANA EKO LESTARI, WENDY SATRIA PANORAMA:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Silvicultural, hydro-orological and economic aspects of a combination of vegetative (Falcataria moluccana-Vigna cylindrica) and terrace systems in soils of different slopes".

Our decision is to: Accept Submission

Smujo Editors
editors@smujo.id

Biodiversitas Journal of Biological Diversity

karyati.hanapi@yahoo.com - Yah

mail.yahoo.com/d/search/name=Smujo%2520Editors&emailAddresses=editors%2540smujo.id&emailAddresses...

[biodiv] Editor Decision

Smujo Editors <smujo.id@gmail.com> Tue, Jul 30, 2019 at 3:48 PM

To: KARYATI, SRI SARMINAH, Karmini, RUJEHAN, VEBI FITRIANA EKO LESTARI and 1 more...

KARYATI, SRI SARMINAH, Karmini, RUJEHAN, VEBI FITRIANA EKO LESTARI, WENDY SATRIA PANORAMA:

The editing of your submission, "Silvicultural, hydro-orological and economic aspects of a combination of vegetative (Falcataria moluccana-Vigna cylindrica) and terrace systems in soils of different slopes," is complete. We are now sending it to production.

Submission URL: https://smujo.id/biodiv/authorDashboard/submission/4171

Smujo Editors
editors@smujo.id

Biodiversitas Journal of Biological Diversity

~~The s~~Silvicultural, hydro-orological and economic aspects of ~~implementation~~ a combination of vegetative (*Falcataria moluccana-Vigna cylindrica*) and terrace systems ~~combination~~ in ~~different~~ soils of different slopes ~~lands~~

Abstract~~.~~: ~~The combination of S~~soil and water conservation techniques ~~between~~involving a combination of vegetative and mechanical systems will ~~be~~ increase the benefits from both consevation aspect as well as economic aspect. ~~Our research~~This study was aimed ~~to~~at ~~investigate~~analysing the silvicultural, hydro-orological~~,~~ and economic aspects of ~~implement~~a combination of vegetative (*Falcataria moluccana* - *Vigna cylindrica*) and terrace system in soils of different ~~soil~~ slopes (a steep and a very steep slope gradient). The silvicultural parameters examined in this study were the ground coverage of *V. cylindrica* growth~~,~~ and survival rate, stem diameter and height of *F. moluccana* trees. The hydro-orological parameters included ~~potential~~ erosion rate, erosion hazard index, erosion hazard class~~,~~ and erosion hazard level. The economic parameters ~~such as~~included total cost, total revenue~~,~~ and ~~benefit were analyzed~~profit. The result showed that the survival rate ~~of *F. moluccana*,~~ ~~ground coverage of *V. cylindrica*~~, diameter increment and height increment of *F. Moluccana*, and ground coverage of *V. cylindrica* ~~o~~in the land with the steep slope (>25-45%) w~~ere~~as 90%, ~~80-90%,~~ 2.02 cm year^{-1}, ~~and~~ 1.54 m year^{-1}, and 80-90%, respectively. The ~~potential~~ erosion rate, erosion hazard index, erosion hazard class, and erosion hazard level in this steep slope w~~ere~~as 0.38 ton ha year^{-1}, 0.03 (low), I (very low), and very low respectively. In the steeper ground (>45%), the survival rate of *F. moluccana* reached 90%, the *V. cylindrica* coverage was 70-79% and the diameter and height increment of *F. moluccana* w~~ere~~as 1.63 cm year^{-1} and 1.19 m year^{-1} respectively. The ~~potential~~ erosion rate was 1.81 ton ha^{-1} year^{-1}, erosion hazard index of 0.13 (low), erosion hazard class ~~of~~was I (very low), and erosion hazard level ~~of~~ was low in the very steep slope land. The profit ~~of~~from *V. cylindrica* ~~yield in planting *F. moluccana V. cylindrica* were~~was Rp~~.~~ 3,8,65,000.00 ha^{-1} cropping season^{-1} and Rp~~.~~ 6,65,000.00 ha^{-1} cropping season^{-1} in steep slope and very steep slope, respectively. The application of the proposed combination of vegetative and terrace system could reduce surface run off and erosion rate ~~for~~in the long term, in addition to ~~as well as~~ providing short term economic benefits ~~for short term~~.

Key words: Economic, hydro-orological, silvicultural, slope, terrace.

Abbreviations: DBH = diameter at breast height; cs = cropping season

Running title: Vegetative and terrace system combination

INTRODUCTION

The over exploitation of natural resources ~~that~~which has exceeded the carrying capacity, ~~and~~coupled with population pressure ~~to~~on land resources~~s~~, will lead to an increase in degraded land~~s~~ area. ~~There is a total area 78 million ha I~~In Indonesia, a total area ~~-~~78 million ha area of land ~~-w~~has been catagorized as degraded lands~~,~~ ~~. From these~~of which, 48 million ha is slightly degraded area, 23 million ha is moderately degraded area~~,~~ and 7 million ha ~~were characterized~~is highly degraded area ~~as slightly degraded area, degraded area, and highly degraded~~ (ADB 2016). The degraded areas are caused by biophysical, social, economical~~,~~ and cultural factors (Matatula 2009). One way to increase ~~land~~the quality ~~that had~~of degraded land is by using soil conditioners, combined with soil and water conservation techniques, organic matter management and~~,~~ ~~a~~ ~~proporsional~~appropriate fertiliz~~er~~ation ~~system~~ based on soil analysis and plant requirement (Tala'ohu & Al-Jabri 2008). The application of cultivation techniques in the marginal and sloping lands has to be combined with the integrated environmental factors (Budiastuti 2013). The policy concept that was found to reduce erosion rate in watershed and sedimentation in reservoir is terrace and crop rotation system (Mardaeni et al. 2014). Edison et al. (2012) recommended vegetative land conservation technology ~~vegetatively~~ to conserve cultivation land (*tegalan*), ~~and or~~ perennial~~s~~ plants in upstream area ~~and~~of *tegalan* ~~to~~ and plantations in downstream area. ~~To increasinge conservation~~

Formatted: Font: Not Italic

Formatted: Font: Not Italic

Formatted: Not Superscript/ Subscript

~~awareness, land conservation education based community proposes trainings on erosion management and soil conservation, conservation education such as vegetative conservation (tree planting program) and mechanical conservation (terrace), etc (Indrayati 2013).~~

The mixed cropping of sengon *(Falcataria moluccana)* and peanut (*Arachis hypogaea*) as well as jabon *(Anthocephalus cadamba)* and soybeans (*Glycine max*) ~~in different soil slopes~~ could be implemented in different soil slopes for rehabilitating and soil conserv~~ingation in~~ slop~~ingeding~~ lands, based on the growth and hydro-orological parameters (Karyati et al. 2018; Sarminah et al. 2018). These two agroforestry systems of *F. Moluccana* - *A.hypogaea* and *A. Cadamba* - *G. max* are feasible and applicable to rehabilitate and conserve the critical lands. Although planting of *G. max* was not profitable ~~to planted~~ in some critical lands, the agroforestry system of *A.cadamba* and *G. max* still ~~gave~~had many benefits from the aspect of ecology and conservation for long terms (Karmini et al. 2017). The production, harvested area, and productivity of *Vigna cylindrica* (long beans) in Indonesia in 2017 w~~ere~~as 381.185 ton, 56.111 hectare, and 6.79 ton hectare^{-1} respectively (Ministry of Agriculture Republic of Indonesia 2018; Statistics of Indonesia 2018). In East Kalimantan, the production of *V. cylindrica* in 2017 was 71.456 quintal, while harvested area and productivity w~~ere~~as 1.361 hectare and 52.50 quintal hectare^{-1}. ~~For these, t~~The productivity of *V. cylindrica* in Samarinda in 2017 was 26.86 quintal hectare^{-1}, ~~resulted from the~~total production ~~of~~was 3.089 quintal and the harvested area of 115 hectare (Ministry of Agriculture Republic of Indonesia 2018; Statistics of East Kalimantan Province 2018).

The total land area of Samarinda City of East Kalimantan Province ~~wa~~is 71.800,00 ha, out of which land area with ~~covered by sloping class lands of~~ less than 2% slope is ~~(~~27.39%~~)~~, 2-15% slope is ~~(~~25.47%~~)~~, 15-25% slope is~~(~~14.81%~~)~~, 25-40% slope is ~~(~~ 15.67%~~)~~, and more than 40% slope is ~~(~~13.02%~~) from total area 71.800,00 ha~~ (Statistics of East Kalimantan Province 2018). ~~The~~A combination of vegetative and terrace techniques ~~in~~of soil and water conservation may be the appropriate choice to rehabilitate sloping lands based on silvicultural, hydro-orological~~,~~ and economic aspects. The plantations of forestry plants is hoped to ~~give~~provide silvicultural, conservation and economic values in a long term program. On the other hand, ~~In the short term, the economic benefit will be expected and provided by~~ plant~~ation~~ing of agricultural plants is expected to provide short term economic benefits.~~.~~ The objectives of this study were to investigate silvicultural, hydro-orological~~,~~ and economic aspects of implementation of a combination of vegetative (*F. moluccana-V. cylindrica*) and terrace systems in different soil slopes, ranging from ~~(a~~ steep ~~and a~~to very steep slope gradients~~)~~.

MATERIALS AND METHODS

Study area

This study was conducted in Educational Forest of Forestry Faculty of Mulawarman University, Lempake District, Samarinda City, ~~Province of~~ East Kalimantan Province. The study ~~took place for~~duration was six months, from January to June 2018. The experimental forest covered a total area of 300 ha, and was located at 0°25'10"–0°25'24" South latitude and 117°14'00"–117°14'14" East longitude, in between kilometers 10 and 13 of t~~T~~he Samarinda-Bontang Highways~~.~~ ~~Kilometers 10 and 13.~~ Administratively, t~~T~~his experimental forest is situated in Tanah Merah Village, North Samarinda District, Samarinda City, East Kalimantan Province ~~administratively~~ (KRUS 2013; KRUS 2014).

The study area received 211.5 mm monthly average rainfall, ~~27.4°C~~ average air temperature is 27.4^{0}C, and relative humidity was 82.2% ~~relative humidity~~ (Karyati 2015). The average daily temperature and relative humidity inside the forest ranged from 23.7°C to ~~-~~30.9°C and 81.4% t0 ~~-~~99.3%, respectively. ~~While in outside the forest, t~~The average daily temperature and relative humidity outside the forest w~~ere~~as 25.9°C-28.8°C and 76.0%-90.0% respectively. The daily average light intensity ranged from 1.08 µmol to 18.41 µmol (Karyati & Ardianto 2016). The climate of Samarinda City was classified as type A climate (a quotient (Q) of 4.8 per cent) based on Schmidt-Ferguson (1951) system which is characterized by highly humidity with a tropical rainforest vegetation (Karyati et al. 2016).

Procedures

Experimental procedures

Experiments were conducted in t~~T~~wo 10 m x 10 m experimental plots which were located in areas with two different slope classes inside the experimental forest. One of t~~T~~hese two experimental plots had a steep slope (>25-45%) and other had a very steep slope (>45%).

~~Terraces sized~~ 2 m wide terraces were ~~established~~made in each experiental plot. Terrace was ~~also~~ completed by ditches sized 25 cm wide and 10 cm depth. Sengon (*F. moluccana*) and long beans (*V. cylindrica*) were planted on both plots. *F. moluccana* trees were planted with a spacing of 3 m × 3 m. *V. cylindrica*, as the intercrop~~ping~~ legumes~~,~~ w~~ere~~as ~~planted~~grown in between the sengon trees. Two ~~10 m × 3 m~~ erosion measurement plots of 10 m × 3 m size were placed ~~o~~in each of the two experimental plots. The growth paremeters were measured once in every month, for ~~during~~ four months period. Plants were maint~~enance~~ained by ~~was done by~~regular watering, weeding, fertilizer application, and pest and ~~plant~~ disease~~s~~ control. ~~The harvesting was done for~~For economic evaluation, only the long beans were harvested, but not ~~on~~ the sengon trees. The measurement of hydro-orological parameters were conducted ~~for~~during 27 times rain events.

Commented [g1]: Not clear. Pl. clarify

Formatted: Font: Not Italic

Formatted: Font: Not Italic

Formatted: Superscript

Formatted: Indent: First line: 0.2"

Analysis of soil properties

The analysis of soil physicochemical properties, such as ~~(~~pH ~~(H_2O), pH (KCl)~~, C organic, total N, P, K, and soil texture,~~)~~ were conducted in Laboratory of Soil Science, Tropical Forest Research Center, Mulawarman University. Soil pH was determined in distilled water and 1 N KCl in a soil to solution ratio of 1:2.5 by the glass electrode method. The C organik and total nitrogen (total N) were analyzed using Walkley & Black and Kjeldahl methods respectively. Soil P and K were analyzed using Bray 1 method.

Commented [g2]: Give References

Commented [g3]: Give Reference for this method.

Data analysis

Silvicultural parameters

The observation and measurement of plant growth w~~ere~~as conducted at the end of every month ~~during~~for four month~~s~~. The observation was carried out on both *F. moluccana* and *V. cylindrica* plants. The parameters studied for *F. moluccana* ~~'s~~ were plant survival rate, tree height, and stem diameter~~, were measured as well as~~For *V. cylindrica* ~~'s,~~ ground coverage and yield was recorded.

Hydro-orological parameter

The ~~measured parameters of~~ hydro-orological parameters measured in this study were surface runoff, potential soil erosion rate, erosion hazard index, erosion hazard class, and erosion hazard level (Hammer 1981). The erosion hazard index categories and erosion hazard level classification are show~~ed~~n in Table 1 and Table 2, respectively. The erosion hazard index is determined as potential erosion rate (ton ha^{-1} $year^{-1}$) divided by tolerable erosion rate (ton ha^{-1} $year^{-1}$) (Hammer 1981):

Table 1. Erosion hazard index categories

Erosion hazard index	Category
< 1.00	Low
1,01-4,00	Moderate
4,01-10,00	High
> 10,01	Very high

Source: Hammer (1981)

Table 2. Erosion hazard level classification

Soil column (cm)	Erosion class				
	I	II	III	IV	V
	Erosion rate (ton ha^{-1} $year^{-1}$)				
	<15	15-<60	60-<180	180-480	>480
Deep (>90)	Very low 0	Low I	Moderate II	Heavy III	Very heavy IV
Intermediate (60-90)	Low I	Moderate II	Heavy III	Very high IV	Very heavy IV
Shallow (30-<60)	Moderate II	Heavy III	Very heavy IV	Very heavy IV	Very heavy IV
Very shallow (<30)	Heavy III	Very heavy IV	Very heavy IV	Very heavy IV	Very heavy IV

Source: Regulation of Directorate General of Watershed Management and Social Forestry, Ministry of Forestry Republic of Indonesia (2013)

Note: 0=Very low; I=Low; II=Moderate; III=Heavy; IV=Very heavy.

Economic analysis

In this study, the ~~economy aspect were~~ analyzed economic aspects were ~~to calculate~~ cost, revenue~~,~~ and profit from ~~the application of~~ long beans as intercropping in sengon~~-~~ (long beans) agroforestry systems. Cost is calculated from price and quantity of inputs, ~~thus~~ revenue is the price of product~~ion~~ed yield, and ~~meanwhile~~ profit is revenue minus cost (Slavin 2009).

RESULTS AND DISCUSSION

Silvicultural aspects

The recorded plant growth parameters of *F. moluccana* and *V. cylindrica* for the two different slope classes are summarized in Table 3. The ~~plant~~ growth ~~parameters~~ of *F. moluccana* and *V. cylindrica* combination were ~~included to categories~~ "moderate" to "very good" in the steep slope and very steep slope. ~~The plant growth parameters of *F. moluccana* and *V. cylindrica* in vegetative and terrace combination system on the two different slope classes are~~

~~summarized in Table 3.~~ The ~~health plant and~~ survival rate of *F. moluccana* ~~o~~in both ~~different~~ slope classes w~~ere~~ ~~categorized to a~~ was "very good" (90%). The ~~healthy plant and~~ ground coverage of *V. cylindrica* in steep slope was better (80-89%) than ~~those~~ in very steep slope (70-79%). Meanwhile, the yield of *V. cylindrica* was also higher (2,500 kg ha^{-1}) in steep slope when compared to the yield in very steep slope (2,100 kg ha^{-1}).

Table 3. The ~~plan~~t growth parameters of *F. moluccana* and *V. cylindrica* in ~~vegetative and terrace combination system on~~ the two ~~differen~~t slope classes

Plant species	Steep slope (>25-45%)				Very steep slope (>45%)			
	Healthy plant~~s~~ (%)	Survival rate (%)	Ground coverage (%)	Yield (kg ha^{-1})	Healthy plant~~s~~ (%)	Survival rate (%)	Ground coverage (%)	Yield (kg ha^{-1})
F. moluccana	90 (Very good)	90 (Very good)	-	-	90 (Very good)	90 (Very good)	-	-
V. cylindrica	80-89 (Good)	-	80-89 (Good)	2,500	70-79 (Moderate)	-	70-79 (Moderate)	2,100

Commented [g4]: How this was measured? Indicate in the methodology part.

The average of *V. cylindrica* yield in this study was almost ~~the same compare~~similar to the average of Samarinda's yield, but lower than ~~those~~ East Kalimantan and Indonesia's yield (Statistics of East Kalimantan Province 2018; Statistics of Indonesia 2018). However, ~~this~~ *V. cylindrica*'s yields obtained in this study was ~~were~~ lower than reported by Wahyu et al. (2018) reported that the productivity of *V. cylindrica* ~~yield~~ in Samboja Subdistrict, Kutai Kartanegara District, East Kalimanatn Province w~~ere~~as 7,010 kg ha^{-1} and 13,640 kg ha^{-1} from monoculture and agroforestry systems, respectively.

The monthly diameter and height increments of *F. moluccana* trees, t~~hat were~~ measured for four months, are ~~illustrated~~provided in Tables 4 and 5. The stem diameter and height increment of *F. moluccana* trees is faster ~~o~~in the slightly steep slope than ~~those o~~in the highly steeper slope. The average stem diameter and height increments of *F. moluccana* were 2.02 cm year^{-1} and 1.54 m year^{-1} ~~o~~in the steep slopes, ~~. The average stem diameter increments of *F. moluccana* trees was~~ and 1.63 cm year^{-1} ~~on the steep slope, while the average height increment was~~and 1.19 m year^{-1}~~.~~, in very steep slope.

The average diameter increment of *F. moluccana* in *F. moluccana* and *V. cylindrica* agroforestry system (on steep and very steep slopes) was lower ~~compared~~ than those in *F. moluccana* and *Arachis hypogaea* agroforestry system (on slight steep and steep slopes) as reported by Sarminah et al. (2018). On the c~~C~~ontra~~sl~~ry, the average height increment of this combination was higher than those reported by Sarminah et al. (2018). Similarly, the diameter increment of *F. moluccana* in this study ~~are~~was also lower than those in agroforestry system, monoculture system, and intensive monoculture system (Swestiani and Purwaningsih 2013; Wahyudi & Panjaitan 2013). However, the average diameter increments of *F. moluccana* trees on the steep slope w~~ere~~as higher than those planted ~~o~~in the conventional monoculture system (Wahyudi & Panjaitan 2013).

Table 4. *Falcataria moluccana* stem diameter increments (mm) ~~o~~in the two different slopes classes

Tree number	Steep slope (>25-45%)					Very steep slope (>45%)				
	D_0	d_1	d_2	d_3	d_4	D_0	d_1	d_2	d_3	d_4
1	12.10	12.85	14.15	16.15	18.68	14.40	15.00	16.05	18.25	21.10
2	9.25	10.00	11.25	12.80	15.00	6.20	6.95	7.90	9.25	11.00
3	8.20	8.90	10.10	11.65	13.85	9.10	9.70	11.00	12.95	15.50
4	5.10	7.80	9.05	10.60	12.50	9.70	10.20	11.25	12.75	15.10
5	12.70	13.65	14.95	16.90	19.25	11.10	11.65	12.90	14.85	17.35
6	8.60	9.55	11.00	12.70	14.75	6.75	7.35	8.30	9.60	11.25
7	5.30	8.00	9.20	10.90	13.00	6.60	7.30	8.40	9.85	11.70
8	7.40	8.15	9.40	11.05	13.00	6.40	7.00	7.95	9.40	11.15
9	10.30	10.90	12.05	13.55	15.50	8.40	9.00	9.95	11.30	13.00
10	10.10	10.80	12.20	13.90	16.10	10.40	11.10	12.15	14.05	16.45
11	5.70	8.50	9.75	11.40	13.55	8.20	8.85	9.80	11.15	12.90
12	10.30	11.20	12.45	14.20	16.60	9.10	10.00	11.50	13.30	15.65
13	11.40	12.10	13.40	15.55	18.20	7.10	7.75	8.80	10.30	12.05
14	6.30	9.10	10.20	12.05	14.15	10.35	11.00	12.20	13.70	15.65
15	10.80	11.50	12.90	14.95	17.55	7.25	8.00	9.10	10.50	12.20
16	4.15	8.75	9.75	11.55	13.65	14.40	15.15	16.50	18.29	20.19
Mean	8.61	10.11	11.36	13.12	15.33	9.09	9.75	10.86	12.47	14.52
SD	2.69	1.81	1.86	1.99	2.17	2.58	2.58	2.66	2.88	3.16
Annual diameter increment	20.18 mm year^{-1} = 2.02 cm year^{-1}					Annual diameter increment: 16~~,~~.27 mm year^{-1}= 1~~,~~.63 cm year^{-1}				

Formatted: Justified

Note: D_0 = initial stem diameter (diameter measurement at the beginning of experiment); d_1, d_2, d_3, d_4 = diameter at the end of the first, second, third, and fourth month after planting; SD=Standard Deviation

Table 5. *F. moluccana* height increments (cm) ~~i~~on the two different slopes

Tree number	Steep slope (>25-45%)					Very steep slope (>45%)				
	H_0	h_1	h_2	h_3	h_4	H_0	h_1	h_2	h_3	h_4
1	153	177	189	205	213	176	197	205	210	220
2	144	157	182	194	206	160	173	182	201	205
3	102	106	111	117	125	143	153	157	164	174
4	176	188	196	202	212	124	136	148	155	166
5	165	183	204	212	227	146	163	166	171	176
6	157	172	194	204	212	123	138	145	158	161
7	167	179	187	200	209	145	157	167	176	188
8	146	167	183	192	204	151	165	178	182	194
9	182	205	219	231	242	146	162	166	175	181
10	184	197	208	219	231	164	177	186	199	206
11	116	131	143	159	177	173	185	189	194	208
12	119	136	148	163	176	152	163	169	175	184
13	159	173	183	195	208	119	134	142	154	162
14	168	184	194	212	220	169	186	190	202	214
15	169	185	198	211	221	134	149	158	167	178
16	137	150	163	172	181	101	113	126	136	144
Mean	153	168	181	193	204	145	159	167	176	185
SD	24,10	26,21	27,59	28,10	28,03	21,03	22,03	20,79	20,69	21,48
Annual height increment	153.75 cm year^{-1} =1.54 m year^{-1}					Annual height increment: 119.1 cm year^{-1} =1.19 m year^{-1}				

Note: H_0 = initial tree height (height measurement at the beginning of experiment); h_1, h_2, h_3, h_4 = height at the end of the first, second, third, and fourth month after planting; SD=Standard Deviation.

Hydro-orological aspects

The hydro-orological aspects ~~could~~were determined by surface runoff and eroded soil mass. ~~The important factors that affecting are rainfall, soil erodibility, length and gradient slope, cover crop, and management practice.~~ Table 6 b~~elow~~ presents data regarding rainfall, eroded soil mass, and surface runoff volume in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system ~~o~~in the two different slope classes. The result showed that the higher rainfall ~~will lead the higher~~results in surface runoff and eroded soil mass. Several factors such as rainfall, slope, cover crop, and management practices ~~were~~have suspected influence on ~~the~~ soil erosion in the study sites. ~~These factors influence soil erosion together.~~ The length and gradient of slope influences soil erosion. ~~which this process was accelerated in the sloping lands.~~ In the steeper slope lands, the rainfall tend to transport the soil particles into lower area faster. It will increase surface runoff and eroded soil mass as well erosion rate. The increasing slope and rain intensity ~~lead~~have increased the runoff rate from 20% to 90% (Chaplot & LeBissonnais 2000).

The implementation of vegetative and terrace system was hoped to reduce the potential soil erosion. Generally, the best recommendation ~~of~~for soil and water conservation technology was to combine the vegetative and mechanical systems~~.~~ ~~B~~because ~~the application of this~~such combinations are usually ~~give the~~ best ~~result to~~for reducinge soil erosion and ~~suppress~~decreasing conservation cost in long term as well as increase~~e~~ing short term economical benefits ~~for short term~~. The *F. moluccana* trees and *V. cylindrica* play a role as cover crop in the sloping lands that could avoid destructive ~~power~~effect of ranfall. In addition, the application of terrace system ~~is hoped~~ could reduce surface runoff and increase water infiltration into the deeper soils. Terrace is used to change the slope geometry which become more flater. ~~slope.~~ It is needed in order to improve sloping land stability (Purnamasari et al. 2014).

The erosion rate is also affected by soil properties, especially soil texture. The soil texture in the study site is silty loam that usually support the greatest diversity of plant life. The silt tends to be loaded with the soluble nutrients required by plants ~~requirement~~. The silt soil~~s is~~ also has ~~the~~ high content of organic matter. The soil in the study plots was categorized as acidic soil, indicated by the pH ~~(H_2O) and pH (KCl)~~ value~~s~~ of lower than 5 and the low content of organic C, total N, P, and K. Fine soil grains ~~is~~ usually tend to have high erosion risk because they do not form ~~a~~ stable soil structures easily because of the fragile cohesion between their particles (A'Yunin 2008).

Table 6. Rainfall, surface runoff volume, and eroded soil mass in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system ~~o~~in the two different slope classes

Rain event	Rainfall (mm)	Surface runoff (liter)		Eroded soil mass (gram/30 m^2)	
		Steep slope (>25-45%)	Very steep slope (>45%)	Steep slope (>25-45%)	Very steep slope (>45%)
1	74	46.74	43.40	128.76	111.59
2	37	12.21	46.74	39.93	631.4
3	14	7.87	46.74	13.51	149.74

Rain event	Rainfall (mm)	Surface runoff (liter)		Eroded soil mass (gram/30 m^2)	
		Steep slope (>25-45%)	Very steep slope (>45%)	Steep slope (>25-45%)	Very steep slope (>45%)
4	20	7.87	46.74	9.22	164.05
5	41	46.74	46.26	119.22	348.13
6	21	14.95	47.21	47.72	214.6
7	36	46.74	46.74	62.95	147.84
8	22	15.74	46.74	32.75	115.41
9	7	4.72	7.79	4.96	25.43
10	15	6.30	46.74	11.06	97.29
11	13	6.23	15.74	6.49	105.87
12	22	23.37	47.21	14.31	75.35
13	31	46.74	47.21	32.43	61.04
14	49	11.8	46.74	18.12	96.33
15	10	6.3	47.21	2.8	57.23
16	10	6.3	17.92	2.03	15.36
17	17	7.87	46.74	2.07	22.89
18	5	8.66	30.69	0.7	24.18
19	9	4.72	31.48	0.38	8.9
20	14	7.87	46.74	0.16	15.26
21	28	7.87	46.74	2.07	34.34
22	41	14.16	47.21	1.14	14.31
23	42	37.77	47.21	3.05	35.29
24	21	11.02	47.21	1.11	25.75
25	27	11.80	46.74	0.72	16.21
26	10	7.87	47.21	0.16	11.45
27	45	15.74	47.21	0.32	8.58
Total	681	445.92	1132.26	558.13	2633.81
Average	25	16.52	41.94	20.67	97.55

The evaluation of erosion hazard index, erosion hazard class, and erosion hazard level could be used as an indicator to determine the erosion status in the area. The hydro-orological parameters recorded in this study are shown in Table 7. The tolerable erosion rate for sloping lands is 25 ton ha^{-1}year^{-1} at a soil depth of more than 100 cm (Rahim 1995). The erosion rate of both steep slope and very steep slope plots were less than 15 ton ha^{-1}year^{-1} while the soil depth in the plot was more than 90 cm. The potential erosion rates in steep slope and very steep slope in studied plots were 0.38 ton ha^{-1}year^{-1} and 1.31 ton ha^{-1}year^{-1} respectively. The erosion hazard index ~~of~~was 0.03 (low) and 0.13 (low) ~~were evaluated in~~for steep slope and very steep slope plots, respectively. The erosion hazard classes (class I) and erosion hazard level ~~o~~in both studied slopes ~~were classified~~belong to “very low” category.

~~The hydro-orological parameters in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system on the two different slope classes are shown in Table 7.~~ The soil erosion rates recorded ~~of agroforestry system of *F. moluccana* and *V. cylindrica* on different slope lands~~ in the current study ~~site~~ was lower than the values reported ~~ose application of~~for some other agroforestry systems (Karyati et al. 2018; Sarminah et al. 2018; Sumarno et al. 2011) as presented in Table 8. This result implied that the combination of vegetative (*F. moluccana* and *V. cylindrica*) and terrace system could be effectively implemented in ~~the~~ different sloping lands.

Table 7. The hydro-orological parameters in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system ~~o~~in the two different slope classes

Slope gradient	Surface runoff rate (m^3 ha^{-1} year^{-1})	Potential erosion rate (ton ha^{-1} year^{-1})	Tolerable erosion rate (ton ha^{-1}year^{-1})	Erosion hazard index	Erosion hazard class	Erosion hazard level
>25-45%	305.77	0.38	25[1)]	0.03 (Low)	I (Very low)	Very low
>45%	776.41	1.81	25[1)]	0.13 (Low)	I (Very low)	Vey low

[1)]Soil depth in the study plot was >100 cm and the tolerable erosion rate for hills or slope lands was 25 ton ha^{-1}year^{-1} (Rahim 1995)

Table 8. ~~The~~Comparison of soil erosion reported in the current study with earlier reports for other ~~in the~~ agroforestry plantation systems

Planting system	Erosion (ton ha^{-1}year^{-1})	Location	Researcher (year)
Soil and water conservation technique and application of agroforestry system	190.08	Ngadipiro Village. Nguntoronadi Sub-district. Wonogiri District. Central Java. Indonesia	Sumarno et al. (2011)
Agroforestry system of *A. cadamba* and *Glycine*		East Kalimantan. Indonesia	Karyati et al. (2018)

max	32.13		
Slope of >15-25%	52.51		
Slope of >25-45%			
Agroforestry system of *F. moluccana* and *A. hypogaea*		East Kalimantan. Indonesia	Sarminah et al. (2018)
Slope of >15-25%	20.05		
Slope of >25-45%	45.50		
Agroforestry system of *F. moluccana* and *V. cylindrica*		East Kalimantan. Indonesia	ThisCurrent study
Slope of >15-25%	0.38		
Slope of >25-45%	1.81		

Economic aspects

The implementation of vegetative (*F. moluccana-V. cylindrica*) and terrace system in different slope classes needsinvolves the cost expenditure to buy planting and other materials., depreciation ofn equipments. and wages of labor. Besides cost expenditure. ThisOn the other hand, implemantation of this method gives revenue and profit, especially from *V. cylindrica* yield. Table 9 shows economic analysis of *V. cylindrica* as intercropping in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system oin the two different slope classes. The material cost was used toinvolved were for buying *F. moluccana* seedlings., *V. cylindrica* seeds, NPK fertilizer, pesticides., plastic strings., gunny sacks., and fertilizers from animal. Fertilizer is given to increase soil fertility. The profit of *F. moluccana-V. cylindrica* plantation in steep slope was Rp 3,8,65,000.00 ha^{-1} cs^{-1} and in very steep slope was Rp 6,65,000.00 ha^{-1} cs^{-1}. This profit was resulted from selling the yield from *V. cylindrica* yield.

The profit offrom *V. cylindrica* yield in steep slope was higher than *A. hypogaea* yield on agroforestry system of *F. moluccana-A. hypogaea* as reported by Karmini et al. (2017). The total cost, total revenue, and profit onrelated to agroforestry system of *F. moluccana* and *A. hypogaea* agroforestry system wereas Rp 10,985,000 ha^{-1} cs^{-1}, Rp 14,000,000 ha^{-1} cs^{-1} and Rp 3,015,000 ha^{-1} cs^{-1}. However, implementation of growing *V. cylindrica* as intercropping in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system oin the two different slope classeslands is highlystill give benefitial when compared to growing *G. max* yield onin agroforestry system *A. Cadamba - G. Mmax* agroforestry system. Karmini et al. (2017) analyzedreported that growing *G. max* in *A. Cadamba - G. max* agroforestry system that theinvolved total cost of Rp 11,019,000.00 ha^{-1} cs^{-1}, total revenue ofwas Rp 3,500,000 ha^{-1} cs^{-1}, and the profit ofwas Rp (-)7,519,000.00 ha^{-1} cs^{-1} .are from *G. max* yield on agroforestry system *A. cadamba-G. max*. The application vegetative (*F. moluccana-V. cylindrica*) and terrace system in different slope classes could add economic values for short term. For long term, *F. moluccana* is also increase added value, especially soil and water conservation.

Formatted: Font: Not Italic

Formatted: Font: Not Italic

Table 9. Economic analysis of growing *V. cylindrica* as intercropping in vegetative (*F. Moluccana - V.cylindrica*) and terrace combination system oin the two different slope classes

Sl. No.	CostItem/activity	Quantity	Unit	Price (Rp)	Total (Rp. ha^{-1}cs^{-1})
Production cost					
Material cost					
1	*F. moluccana* seedlings	1350.00	units ha^{-1}	3,000.00	4,050,000.00
2	*V. cylindrica* seeds	350.00	units ha^{-1} cs^{-1}	15,000.00	5,250,000.00
3	NPK fertilizer	100.00	kg ha^{-1} cs^{-1}	15,000.00	1,500,000.00
4	Pesticides	25.00	kg ha^{-1} cs^{-1}	30,000.00	750,000.00
5	Plastic strings	1.00	units ha^{-1} cs^{-1}	30,000.00	30,000.00
6	Gunny sacks	20.00	units ha^{-1} cs^{-1}	2,000.00	40,000.00
7	Fertilizer from animal	50.00	units ha^{-1} cs^{-1}	25,000.00	1,250,000.00
	Sub total				12,870,000.00
Depreciation cost					
8	Hoe	2.00	units ha^{-1}	125,000.00	20,833.33
9	Chopper	2.00	units ha^{-1}	100,000.00	16,666.67
10	Sickle	2.00	units ha^{-1}	60,000.00	10,000.00
11	Sprayer	1.00	units ha^{-1}	350,000.00	17,500.00
	Sub total				65,000.00
Labor cost					
12	Land preparation	7.00	days ha^{-1} cs^{-1}	100.000.00	700,000.00
13	Planting	6.00	days ha^{-1} cs^{-1}	100.000.00	600,000.00

Formatted: English (United States)

Formatted: English (United States)

Formatted: English (United States)

Formatted: English (United States)

Formatted: English (United States)

14	Fertilizing	4.00	days ha^{-1} cs^{-1}	100.000.00	400,000.00
15	Weeding	5.00	days ha^{-1} cs^{-1}	100.000.00	500,000.00
16	Pest and disease~~s~~ controlling	4.00	days ha^{-1} cs^{-1}	100.000.00	400,000.00
17	Harvesting	6.00	days ha^{-1} cs^{-1}	100.000.00	600,000.00
	Sub total				3,200,000.00
Total cost					16,135,000.00
Total revenue from *V. cylindrica*					
	Steep slope plot (>25-45%)	2,500.00	kg ha^{-1}	8,000.00	20,000,000.00
	Very steep slope plot (>45%)	2,100.00	kg ha^{-1}	8,000.00	16,800,000.00
Profit		Steep slope plot (>25-45%)			3~~,~~8,65,000.00
		Very steep slope plot (>45%)			6,65,000.00

Note: cs = cropping season

The implementation of a combination of vegetative and terrace system ~~combination in~~for soil and water conservation could be apply~~y~~ied in the different slope lands. This ~~application~~practice will ~~give~~be benefitial based on silvicultural, hydro-orological~~l~~, and economic aspects. ~~The combination vegetative and civil technique still shows good growth paramaters. The hydro-orological parameters in this implementation is hoped can reduce surface runoff rate and erosion rate.~~ The short tem economic benefit ~~will be given~~is provided by agricultural yield ~~as~~ from the cropp~~ping~~ plant ~~in the short term~~. In long term, this ~~application~~practice is benefitial in terms of ~~will give~~ soil and water conservation and environment aspects. The ~~important~~ information of this study on silvicultural, hydro-orological~~,~~ and economic aspects could be used for ~~basic~~ recommend~~ation~~ing ~~in relation to~~ alternative agroforestry systems ~~for~~in small scale, and soil conservation programs ~~for~~ in a wide scale~~. The basic data could be used as consideration by~~for all stakeholders~~,~~ including farmers, foresters, private parties and the ~~goverment~~governmental agencies ~~in terms of~~concerned with land management and soil conservation activities.

ACKNOWLEDGEMENTS

The authors wish to express~~ed our~~their thanks to Ministry of Research, Tehnology and Higher Education, Republic of Indonesia for supporting *Hibah Penelitian Strategis Nasional Institusi*.

REFERENCES

ADB. 2016. Indonesia Country Water Assessment. Manila. (PATA 8432-INO). ADB, Mandaluyong City, Philippines.
A'Yunin Q. 2008 Prediksi Tingkat Bahaya Erosi dengan Metode USLE di Lereng Timur Gunung Sindoro. Skripsi. Universitas Sebelas Maret. Surakarta.
Budiastuti S. 2013. Sistem agroforestri sebagai alternatif hadapi pergeseran musim guna pencapaian keamanan pangan. Ekosains 5 (1): 1-5.
Caliskan S, Arslan M, Uremis I, Caliskan ME. 2007. The effects of row spacing on yield and yield components of full season and double-cropped soybean. Turk J Agric For 31: 147-154.
Chaplot V, LeBissonnais Y. 2000. Field measurements of interrill erosion under different slopes and plot sizes. Earth Surf Proces Landf 25: 145-153.
Edison, Bisri M, Suhartanto E. 2012. Studi teknologi konservasi untuk menurunkan laju erosi pada Sub DAS Sombe Lewara Provinsi Sulawesi Tengah. Jurnal Teknik Pengairan 3(2): 204–210.
Hammer WI. 1981. Second soil conservation consultant report. AGOF/INS/78/006. Tech. Note No. 10. Centre for Soil Research, Bogor.
~~Indrayati A. 2013. Peningkatan ketahanan terhadap risiko bencana melalui pendidikan konservasi lahan berbasis masyarakat di dataran tinggi Dieng. Jurnal Geografi 10(2): 154-166.~~
Karmini, Sarminah S, Karyati. 2017. Economic analysis of groundnut (*Arachis hypogaea*) and soybean (*Glycine max*) as intercropping plants in two agroforestry systems. Biodiversitas 18 (2): 483-493.
Karyati. 2015. Pengaruh iklim terhadap jumlah kunjungan wisata di Kebun Raya Unmul Samarinda (KRUS). Jurnal Riset Kaltim 3(1): 51-59.
Karyati, Ardianto S. 2016. Dinamika suhu tanah pada kedalaman berbeda di Hutan Pendidikan Fakultas Kehutanan Universitas Mulawarman. Jurnal Riset Kaltim 4 (1): 1-12.
Karyati, Ardiyanto S, Syafrudin M. 2016. Fluktuasi iklim mikro di Hutan Pendidikan Fakultas Kehutanan Universitas Mulawarman. Agrifor 15(1): 83-92.
Karyati, Sarminah S, Karmini, Simangunsong G, Tamba J. 2018. The mixed cropping of *Anthocephalus cadamba* and *Glycine max* for rehabilitating sloping lands. Biodiversitas 19(6): 2088-2095
KRUS. 2013. Laporan Tahunan Kebun Raya Unmul Samarinda (KRUS) Tahun 2013. KRUS, Samarinda.
KRUS. 2014. Laporan Tahunan Kebun Raya Unmul Samarinda (KRUS) Tahun 2014. KRUS, Samarinda.
Mardaeni, Munir A, Useng D. 2014. Skenario penggunaan lahan untuk mereduksi erosi Berbasis Fuzzy Multi Attribute Decision Making Di DAS Jeneberang J. Sains & Teknologi, 14(3): 277–284.
Matatula J. 2009. Upaya rehabilitasi lahan kritis dengan penerapan teknologi agroforestry sistem silvopastoral di Desa Oebola Kecamatan Fatuleu Kabupaten Kupang. Inotek 13(1): 63-74.
Ministry of Agriculture Republic of Indonesia. 2018. Agricultural Statistics 2018. Ministry of Agriculture Republic of Indonesia, Jakarta.
Purnamasari DA, Surjandari NS, As'ad S. 2014. Desain terasering pada lereng Sungai Gajah Putih Surakarta. Jurnal Matriks Teknik Sipil 2(1): 151-161.
Rahim SE. 1995. Erosi Tanah dan Pemodelan Pendugaannya dalam Dinamika Lingkungan Hidup Sumatera Selatan. PPLH Lembaga Penelitian Universitas Sriwijaya.

Regulation of Directorate General of Watershed Management and Social Forestry, Ministry of Forestry Republic of Indonesia Number: P.4/V-SET/2013.
Sarminah S, Karyati, Karmini, Simbolon J, Tambunan E. 2018. Rehabilitation and soil conservation of degraded land using sengon (*Falcataria moluccana*) and peanut (*Arachis hypogaea*) agroforestry system. Biodiversitas 19 (1): 222-28.
Slavin SL. 2009. Economics. McGraw-Hill Irwin, New York.
Sumarno, Winarno J, Prastomo I. 2011. Kajian pengelolaan lahan berdasarkan tingkat bahaya erosi dan pola konservasi tanah dan air di Desa Ngadipiro Kecamatan Nguntoronadi, Kabupaten Wonogiri. Sains Tanah-Jurnal Ilmu Tanah dan Agroklimatologi 8 (1): 13-22.
Swestiani D, Purwaningsih S. 2013. Production of groundnut (*Arachis hypogaea* L.) in agroforestry based sengon and manglid timbers. Agroforestry 1(2): 71-82.
Statistics of East Kalimantan Province. 2018. Kalimantan Timur Province in Figure 2018. BPS Statistics of East Kalimantan Province, Samarinda.
Statistics of Indonesia. 2018. Indonesia in number 2017. Jakarta: Statistics of Indonesia.
Tala'ohu SH, Al-Jabri M. 2008. Mengatasi degradasi lahan melalui aplikasi pembenah tanah. Jurnal Zeolit Indonesia 7(1): 22-34.
Wahyu I, Pranoto H, Supriyanto B. 2018. Kajian produktivitas tanaman semusim pada sistem agroforestri di Kecamatan Samboja Kabupaten Kutai Kartanegara. Agroekoteknologi Tropika Lembab 1(1): 24-33.
Wahyudi, Panjaitan S. 2013. Perbandingan sistem agroforestri, monokultur intensif, dan monokultur konvensional dalam pembangunan hutan tanaman sengon. Prosiding Seminar Nasional Agroforestri 165-171.

~~The s~~Silvicultural, hydro-orological and economic aspects of ~~implementation~~ a combination of –vegetative (*Falcataria moluccana*-*Vigna cylindrica*) and terrace systems ~~combination~~ in ~~different~~ soils of different slopes ~~lands~~

Abstract~~.~~**:** ~~The combination of S~~soil and water conservation techniques ~~between~~involving a combination of –vegetative and mechanical systems will ~~be~~ increase the benefits from both consevation aspect as well as economic aspect. ~~Our research~~This study was aimed ~~to~~at ~~investigate~~analysing the silvicultural, hydro-orological~~,~~ and economic aspects of ~~implement~~a combination of vegetative (*Falcataria moluccana* - *Vigna cylindrica*) and terrace system in soils of different ~~soil~~ slopes (a steep and a very steep slope gradient). The silvicultural parameters examined in this study were the ground coverage of *V. cylindrica* growth~~,~~ and survival rate, stem diameter and height of *F. moluccana* trees. The hydro-orological parameters included ~~potential~~ erosion rate, erosion hazard index, erosion hazard class~~,~~ and erosion hazard level. The economic parameters ~~such as~~included total cost, total revenue~~,~~ and ~~benefit were analyzed~~profit. The result showed that the survival rate ~~of *F. moluccana*,~~ ~~ground coverage of *V. cylindrica*~~, diameter increment and height increment of *F.* ~~M~~m*oluccana*, and ground coverage of *V. cylindrica* ~~o~~in the land with the steep slope (>25-45%) w~~ere~~as 90%, ~~80-90%,~~ 2.02 cm year^{-1}, ~~and~~ 1.54 m year^{-1}, and 80-90%, respectively. The ~~potential~~ erosion rate, erosion hazard index, erosion hazard class, and erosion hazard level in this steep slope w~~ere~~as 0.38 ton ha year^{-1}, 0.03 (low), I (very low), and very low, respectively. In the steeper ground (>45%), the survival rate of *F. moluccana* reached 90%, the *V. cylindrica* coverage was 70-79% and the diameter and height increment of *F. moluccana* w~~ere~~as 1.63 cm year^{-1} and 1.19 m year^{-1}, respectively. The ~~potential~~ erosion rate was 1.81 ton ha^{-1} year^{-1}, erosion hazard index of 0.13 (low), erosion hazard class ~~of~~was I (very low), and erosion hazard level ~~of~~ was low in the very steep slope land. The profit ~~of~~from *V. cylindrica* ~~yield in planting *F. moluccana* - *V. cylindrica* were~~was Rp~~.~~ 3,8,65,000.00 ha^{-1} cropping season^{-1} and Rp~~.~~ 6,65,000.00 ha^{-1} cropping season^{-1} in steep slope and very steep slope, respectively. The application of the proposed combination of vegetative and terrace system could reduce surface run off and erosion rate ~~for~~in the long term, in addition to ~~as well as~~ providing short term economic benefits ~~for short term~~.

Key words: Economic, hydro-orological, silvicultural, slope, terrace.

Abbreviations: DBH = diameter at breast height; cs = cropping season

Running title: Vegetative and terrace system combination

INTRODUCTION

The over exploitation of natural resources ~~that~~which has exceeded the carrying capacity, ~~and~~coupled with population pressure ~~to~~on land resources~~s~~, will lead to an increase in degraded land~~s~~ area. ~~There is a total area 78 million ha I~~in Indonesia, ~~a total area~~ 78 million ha area of land ~~w~~has been catagorized as degraded land~~s~~, ~~. From these~~of which, 48 million ha is slightly degraded area, 23 million ha is moderately degraded area~~,~~ and 7 million ha ~~were characterized~~is highly degraded area ~~as slightly degraded area, degraded area, and highly degraded~~ (ADB 2016). The degraded areas are caused by biophysical, social, economical~~,~~ and cultural factors (Matatula 2009). One way to increase ~~land~~the quality ~~that had~~of degraded land is by using soil conditioners, combined with soil and water conservation techniques, organic matter management and~~,~~ ~~a proporsional~~appropriate fertiliz~~er~~ation ~~system~~ based on soil analysis and plant requirement (Tala'ohu & Al-Jabri 2008). The application of cultivation techniques in the marginal and sloping lands has to be combined with the integrated environmental factors (Budiastuti 2013). The policy concept that was found to reduce erosion rate in watershed and sedimentation in reservoir is terrace and crop rotation system (Mardaeni et al. 2014). Edison et al. (2012) recommended vegetative land conservation technology ~~vegetatively~~ to conserve cultivation land (*tegalan*), ~~and or~~ perennial~~s~~ plants in upstream area ~~and~~of *tegalan* ~~to~~ and plantations in downstream area. ~~To increasinge conservation~~

Formatted: Font: Not Italic

Formatted: Font: Not Italic

Formatted: Not Superscript/ Subscript

~~awareness, land conservation education based community proposes trainings on erosion management and soil conservation, conservation education such as vegetative conservation (tree planting program) and mechanical conservation (terrace), etc (Indrayati 2013).~~

The mixed cropping of sengon (Falcataria moluccana) and peanut (*Arachis hypogaea*) as well as jabon (Anthocephalus cadamba) and soybeans (*Glycine max*) ~~in different soil slopes~~ could be implemented in different soil slopes for rehabilitating and soil conserv~~ing~~ation in slop~~ing~~eding lands, based on the growth and hydro-orological parameters (Karyati et al. 2018; Sarminah et al. 2018). These two agroforestry systems of *F. m~~M~~oluccana - A. hypogaea* and *A. c~~C~~adamba - G. max* are feasible and applicable to rehabilitate and conserve the critical lands. Although planting of *G. max* was not profitable ~~to planted~~ in some critical lands, the agroforestry system of *A.cadamba* and *G. max* still ~~gave~~had many benefits from the aspect of ecology and conservation for long terms (Karmini et al. 2017). The production, harvested area, and productivity of *Vigna cylindrica* (long beans) in Indonesia in 2017 w~~ere~~as 381,~~.~~185 ton; 56,~~.~~111 hectare, and 6.79 ton hectare^{-1}, respectively (Ministry of Agriculture Republic of Indonesia 2018; Statistics of Indonesia 2018). In East Kalimantan, the production of *V. cylindrica* in 2017 was 71,~~.~~456 quintal, while harvested area and productivity w~~ere~~as 1,~~.~~361 hectare and 52.50 quintal hectare^{-1}. ~~For these, t~~The productivity of *V. cylindrica* in Samarinda in 2017 was 26.86 quintal hectare^{-1}, ~~resulted from the~~total production ~~of~~was 3,~~.~~089 quintal and the harvested area of 115 hectare (Ministry of Agriculture Republic of Indonesia 2018; Statistics of East Kalimantan Province 2018).

The total land area of Samarinda City of East Kalimantan Province ~~wa~~is 71.800,00 ha, out of which land area with ~~covered by sloping class lands of~~ less than 2% slope is ~~(~~27.39%~~)~~, 2-15% slope is ~~(~~25.47%~~)~~, 15-25% slope is~~(~~14.81%~~)~~, 25-40% slope is ~~(~~ 15.67%~~)~~, and more than 40% slope is ~~(~~13.02% ~~) from total area 71.800,00 ha~~ (Statistics of East Kalimantan Province 2018). ~~The~~A combination of vegetative and terrace techniques ~~in~~of soil and water conservation may be the appropriate choice to rehabilitate sloping lands based on silvicultural, hydro-orological~~,~~ and economic aspects. The plantations of forestry plants is hoped to ~~give~~provide silvicultural, conservation and economic values in a long term program. On the other hand, ~~In the short term, the economic benefit will be expected and provided by~~ plant~~ation~~ing of agricultural plants is expected to provide short term economic benefits.~~.~~ The objectives of this study were to investigate silvicultural, hydro-orological~~,~~ and economic aspects of implementation of a combination of vegetative (*F. moluccana-V. cylindrica*) and terrace systems in different soil slopes, ranging from ~~(a~~ steep ~~and a~~to very steep slope gradients~~)~~.

MATERIALS AND METHODS

Study area

This study was conducted in Educational Forest of Forestry Faculty of Mulawarman University, Lempake District, Samarinda City, ~~Province of~~ East Kalimantan Province. The study ~~took place for~~duration was six months, from January to June 2018. The experimental forest covered a total area of 300 ha~~,~~ and was located at 0°25'10"–0°25'24" South latitude and 117°14'00"–117°14'14" East longitude, in between kilometers 10 and 13 of t~~T~~he Samarinda-Bontang Highways. ~~Kilometers 10 and 13.~~ Administratively, t~~T~~his experimental forest is situated in Tanah Merah Village, North Samarinda District, Samarinda City, East Kalimantan Province ~~administratively~~ (KRUS 2013; KRUS 2014).

The study area received 211.5 mm monthly average rainfall, ~~27.4°C~~ average air temperature is 27.4^{0}C, and relative humidity was 82.2% ~~relative humidity~~ (Karyati 2015). The average daily temperature and relative humidity inside the forest ranged from 23.7°C to ~~-~~30.9°C and 81.4% t0 ~~-~~99.3%, respectively. ~~While in outside the forest, t~~The average daily temperature and relative humidity outside the forest w~~ere~~as 25.9°C-28.8°C and 76.0%-90.0%, respectively. The daily average light intensity ranged from 1.08 µmol to 18.41 µmol (Karyati & Ardianto 2016). The climate of Samarinda City was classified as type A climate (a quotient (Q) of 4.8 per cent) based on Schmidt-Ferguson (1951) system which is characterized by highly humidity with a tropical rainforest vegetation (Karyati et al. 2016).

Procedures

Experimental procedures

Experiments were conducted in t~~T~~wo 10 m x 10 m experimental plots ~~which~~ were located in areas with two different slope classes inside the experimental forest. One of t~~T~~hese two experimental plots had a steep slope (>25-45%) and other had ~~a~~ very steep slope (>45%).

~~Terraces sized~~ 2 m wide terraces were ~~established~~made in each experiental plot. Terrace was ~~also~~ completed by ditches sized 25 cm wide and 10 cm depth. Sengon (*F. moluccana*) and long beans (*V. cylindrica*) were planted on both plots. *F. moluccana* trees were planted with a spacing of 3 m × 3 m. *V. cylindrica*, as the intercrop~~ping~~ legumes, w~~ere~~as ~~planted~~grown in between the sengon trees. Two ~~10 m × 3 m~~ erosion measurement plots of 10 m × 3 m size were placed ~~o~~in each of the two experimental plots. The growth paremeters were measured once in every month, for ~~during~~ four months period. Plants were maint~~enance~~ained by ~~was done by~~regular watering, weeding, fertilizer application, and pest and ~~plant~~ diseases control. ~~The harvesting was done for~~For economic evaluation, only the long beans were harvested, but not ~~on~~ the sengon trees. The measurement of hydro-orological parameters were conducted ~~for~~during 27 times rain events.

Commented [g1]: Not clear. Pl. clarify

Formatted: Font: Not Italic

Formatted: Font: Not Italic

Formatted: Superscript

Formatted: Indent: First line: 0.2"

Analysis of soil properties

The analysis of soil physicochemical properties, such as ~~(~~pH ~~(H$_2$O), pH (KCl)~~, C organic, total N, P, K, and soil texture,~~)~~ were conducted in Laboratory of Soil Science, Tropical Forest Research Center, Mulawarman University. Soil pH was determined in distilled water and 1 N KCl in a soil to solution ratio of 1:2.5 by the glass electrode method. The C organik and total nitrogen (total N) were analyzed using Walkley & Black method (1934) and Kjeldahl method (1883)~~s~~, respectively. Soil P and K were analyzed using Bray 1 method.

Data analysis

Silvicultural parameters

The observation and measurement of plant growth w~~ere~~as conducted at the end of every month ~~during~~for four months. The observation was carried out on both *F. moluccana* and *V. cylindrica* plants. The parameters studied for *F. moluccana*~~'s~~ were plant survival rate, tree height, and stem diameter. ~~were measured as well as~~For *V. cylindrica*~~'s,~~ ground coverage and yield was recorded. The plant health was measured for both *F. moluccana* and *V. cylindrica*. A healthy plant was characterized as a plant with a normal heigh, fresh green leaves, normal stem, and no disease/pests and weed (Ministry of Forestry Republic of Indonesia 2009).

Hydro-orological parameter

The ~~measured parameters of~~ hydro-orological parameters measured in this study were surface runoff, potential soil erosion rate, erosion hazard index, erosion hazard class, and erosion hazard level (Hammer 1981). The erosion hazard index categories and erosion hazard level classification are show~~ed~~n in Table 1 and Table 2, respectively. The erosion hazard index is determined as potential erosion rate (ton ha^{-1} year^{-1}) divided by tolerable erosion rate (ton ha^{-1} year^{-1}) (Hammer 1981):

Table 1. Erosion hazard index categories

Erosion hazard index	Category
< 1.00	Low
1,01-4,00	Moderate
4,01-10,00	High
> 10,01	Very high

Source: Hammer (1981)

Table 2. Erosion hazard level classification

Soil column (cm)	Erosion class				
	I	II	III	IV	V
	Erosion rate (ton ha^{-1} year^{-1})				
	<15	15-<60	60-<180	180-480	>480
Deep (>90)	Very low 0	Low I	Moderate II	Heavy III	Very heavy IV
Intermediate (60-90)	Low I	Moderate II	Heavy III	Very high IV	Very heavy IV
Shallow (30-<60)	Moderate II	Heavy III	Very heavy IV	Very heavy IV	Very heavy IV
Very shallow (<30)	Heavy III	Very heavy IV	Very heavy IV	Very heavy IV	Very heavy IV

Source: Regulation of Directorate General of Watershed Management and Social Forestry, Ministry of Forestry Republic of Indonesia (2013)

Note: 0=Very low; I=Low; II=Moderate; III=Heavy; IV=Very heavy.

Economic analysis

In this study, the ~~economy aspect were~~ analyzed economic aspects were ~~to calculate~~ cost, revenue~~,~~ and profit from ~~the application of~~ long beans as intercropping in sengon~~-~~ (long beans) agroforestry systems. Cost is calculated from price and quantity of inputs, ~~thus~~ revenue is the price of produc~~tion~~ed yield, and ~~meanwhile~~ profit is revenue minus cost (Slavin 2009).

RESULTS AND DISCUSSION

Silvicultural aspects

The recorded plant growth parameters of *F. moluccana* and *V. cylindrica* for the two different slope classes are summarized in Table 3. The ~~plant~~ growth ~~parameters~~ of *F. moluccana* and *V. cylindrica* combination were ~~included to~~

Commented [g2]: Give References

Formatted: Highlight

Commented [g3]: Give Reference for this method.

Formatted: Highlight

~~categories~~ “moderate” to “very good” in the steep slope and very steep slope. ~~The plant growth parameters of *F. moluccana* and *V. cylindrica* in vegetative and terrace combination system on the two different slope classes are summarized in Table 3.~~ The ~~health plant and~~ survival rate of *F. moluccana* ~~o~~in both ~~different~~ slope classes w~~ere~~ ~~categorized to a~~ was “very good” (90%). The ~~healthy plant and~~ ground coverage of *V. cylindrica* in steep slope was better (80-89%) than ~~those~~ in very steep slope (70-79%). Meanwhile, the yield of *V. cylindrica* was also higher (2,500 kg ha^{-1}) in steep slope when compared to the yield in very steep slope (2,100 kg ha^{-1}).

Table 3. The ~~plan~~t growth parameters of *F. moluccana* and *V. cylindrica* in ~~vegetative and terrace combination system on~~ the two ~~differen~~t slope classes

Plant species	Steep slope (>25-45%)				Very steep slope (>45%)			
	Healthy plants (%)	Survival rate (%)	Ground coverage (%)	Yield (kg ha^{-1})	Healthy plants (%)	Survival rate (%)	Ground coverage (%)	Yield (kg ha^{-1})
F. moluccana	90 (Very good)	90 (Very good)	-	-	90 (Very good)	90 (Very good)	-	-
V. cylindrica	80-89 (Good)	-	80-89 (Good)	2,500	70-79 (Moderate)	-	70-79 (Moderate)	2,100

Commented [g4]: How this was measured? Indicate in the methodology part.

The average of *V. cylindrica* yield in this study was almost ~~the same compare~~similar to the average of Samarinda’s yield, but lower than ~~those~~ East Kalimantan and Indonesia’s yield (Statistics of East Kalimantan Province 2018; Statistics of Indonesia 2018). However, ~~this~~ *V. cylindrica*’s yields obtained in this study was ~~were~~ lower than reported by Wahyu et al. (2018). Wahyu et al. (2018) reported that the productivity of *V. cylindrica* ~~yield~~ in Samboja Subdistrict, Kutai Kartanegara District, East Kalimanatn Province w~~ere~~as 7,010 kg ha^{-1} and 13,640 kg ha^{-1} from monoculture and agroforestry systems, respectively.

The monthly diameter and height increments of *F. moluccana* trees, ~~that were~~ measured for four months, are ~~illustrated~~provided in Tables 4 and 5. The stem diameter and height increment of *F. moluccana* trees is faster ~~o~~in the slightly steep slope than ~~those o~~in the highly steeper slope. The average stem diameter and height increments of *F. moluccana* were 2.02 cm year^{-1} and 1.54 m year^{-1} ~~o~~in the steep slopes, ~~. The average stem diameter increments of *F. moluccana* trees was~~ and 1.63 cm year^{-1} ~~on the steep slope, while the average height increment was~~and 1.19 m year^{-1}~~.~~, in very steep slope.

The average diameter increment of *F. moluccana* in *F. moluccana* and *V. cylindrica* agroforestry system (on steep and very steep slopes) was lower ~~compared~~ than those in *F. moluccana* and *Arachis hypogaea* agroforestry system (on slight steep and steep slopes) as reported by Sarminah et al. (2018). On the c~~C~~ontra~~sl~~ry, the average height increment of this combination was higher than those reported by Sarminah et al. (2018). Similarly, the diameter increment of *F. moluccana* in this study ~~are~~was also lower than those in agroforestry system, monoculture system, and intensive monoculture system (Swestiani and Purwaningsih 2013; Wahyudi & Panjaitan 2013). However, the average diameter increments of *F. moluccana* trees on the steep slope w~~ere~~as higher than those planted ~~o~~in the conventional monoculture system (Wahyudi & Panjaitan 2013).

Table 4. *Falcataria moluccana* stem diameter increments (mm) ~~o~~in the two different slopes classes

Tree number	Steep slope (>25-45%)					Very steep slope (>45%)				
	D_0	d_1	d_2	d_3	d_4	D_0	d_1	d_2	d_3	d_4
1	12.10	12.85	14.15	16.15	18.68	14.40	15.00	16.05	18.25	21.10
2	9.25	10.00	11.25	12.80	15.00	6.20	6.95	7.90	9.25	11.00
3	8.20	8.90	10.10	11.65	13.85	9.10	9.70	11.00	12.95	15.50
4	5.10	7.80	9.05	10.60	12.50	9.70	10.20	11.25	12.75	15.10
5	12.70	13.65	14.95	16.90	19.25	11.10	11.65	12.90	14.85	17.35
6	8.60	9.55	11.00	12.70	14.75	6.75	7.35	8.30	9.60	11.25
7	5.30	8.00	9.20	10.90	13.00	6.60	7.30	8.40	9.85	11.70
8	7.40	8.15	9.40	11.05	13.00	6.40	7.00	7.95	9.40	11.15
9	10.30	10.90	12.05	13.55	15.50	8.40	9.00	9.95	11.30	13.00
10	10.10	10.80	12.20	13.90	16.10	10.40	11.10	12.15	14.05	16.45
11	5.70	8.50	9.75	11.40	13.55	8.20	8.85	9.80	11.15	12.90
12	10.30	11.20	12.45	14.20	16.60	9.10	10.00	11.50	13.30	15.65
13	11.40	12.10	13.40	15.55	18.20	7.10	7.75	8.80	10.30	12.05
14	6.30	9.10	10.20	12.05	14.15	10.35	11.00	12.20	13.70	15.65
15	10.80	11.50	12.90	14.95	17.55	7.25	8.00	9.10	10.50	12.20
16	4.15	8.75	9.75	11.55	13.65	14.40	15.15	16.50	18.29	20.19
Mean	8.61	10.11	11.36	13.12	15.33	9.09	9.75	10.86	12.47	14.52
SD	2.69	1.81	1.86	1.99	2.17	2.58	2.58	2.66	2.88	3.16

Annual diameter increment	20.18 mm $year^{-1}$ = 2.02 cm $year^{-1}$	Annual diameter increment	16~~,~~.27 mm $year^{-1}$= 1~~,~~.63 cm $year^{-1}$

Formatted: Justified

Note: D_0 = initial stem diameter (diameter measurement at the beginning of experiment); d_1,d_2, d_3, d_4 = diameter at the end of the first, second, third, and fourth month after planting; SD=Standard Deviation

Table 5. *F. moluccana* height increments (cm) ~~i~~on the two different slopes

Tree number	Steep slope (>25-45%)					Very steep slope (>45%)				
	H_0	h_1	h_2	h_3	h_4	H_0	h_1	h_2	h_3	h_4
1	153	177	189	205	213	176	197	205	210	220
2	144	157	182	194	206	160	173	182	201	205
3	102	106	111	117	125	143	153	157	164	174
4	176	188	196	202	212	124	136	148	155	166
5	165	183	204	212	227	146	163	166	171	176
6	157	172	194	204	212	123	138	145	158	161
7	167	179	187	200	209	145	157	167	176	188
8	146	167	183	192	204	151	165	178	182	194
9	182	205	219	231	242	146	162	166	175	181
10	184	197	208	219	231	164	177	186	199	206
11	116	131	143	159	177	173	185	189	194	208
12	119	136	148	163	176	152	163	169	175	184
13	159	173	183	195	208	119	134	142	154	162
14	168	184	194	212	220	169	186	190	202	214
15	169	185	198	211	221	134	149	158	167	178
16	137	150	163	172	181	101	113	126	136	144
Mean	153	168	181	193	204	145	159	167	176	185
SD	24,10	26,21	27,59	28,10	28,03	21,03	22,03	20,79	20,69	21,48
Annual height increment	153.75 cm $year^{-1}$ =1.54 m $year^{-1}$					Annual height increment 119.1 cm $year^{-1}$ =1.19 m $year^{-1}$				

Note: H_0 = initial tree height (height measurement at the beginning of experiment); h_1, h_2, h_3, h_4 = height at the end of the first, second, third, and fourth month after planting; SD=Standard Deviation.

Hydro-orological aspects

The hydro-orological aspects ~~could~~were determined by surface runoff and eroded soil mass. ~~The important factors that affecting are rainfall, soil erodibility, length and gradient slope, cover crop, and management practice.~~ Table 6 below presents data regarding rainfall, eroded soil mass, and surface runoff volume in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system ~~o~~in the two different slope classes. The result showed that the higher rainfall ~~will lead the higher~~results in surface runoff and eroded soil mass. Several factors such as rainfall, slope, cover crop, and management practices ~~were~~have suspected influence on ~~the~~ soil erosion in the study sites. ~~These factors influence soil erosion together.~~ The length and gradient of slope influences soil erosion.~~ which this process was accelerated in the sloping lands.~~ In the steeper slope lands, the rainfall tend to transport the soil particles into lower area faster. It will increase surface runoff and eroded soil mass as well erosion rate. The increasing slope and rain intensity ~~lead~~have increased the runoff rate from 20% to 90% (Chaplot & LeBissonnais 2000).

The implementation of vegetative and terrace system was hoped to reduce the potential soil erosion. Generally, the best recommendation ~~of~~for soil and water conservation technology was to combine the vegetative and mechanical systems~~.~~ ~~B~~because ~~the application of this~~such combinations are usually ~~give the~~ best ~~result to~~for reducinge soil erosion and ~~suppress~~decreasing conservation cost in long term as well as increase~~e~~ing short term economical benefits~~ for short term~~. The *F. moluccana* trees and *V. cylindrica* play a role as cover crop in the sloping lands that could avoid destructive ~~power~~effect of ranfall. In addition, the application of terrace system ~~is hoped~~ could reduce surface runoff and increase water infiltration into the deeper soils. Terrace is used to change the slope geometry which become more flater~~. slope.~~ It is needed in order to improve sloping land stability (Purnamasari et al. 2014).

The erosion rate is also affected by soil properties, especially soil texture. The soil texture in the study site is silty loam that usually support the greatest diversity of plant life. The silt tends to be loaded with the soluble nutrients required by plants~~ requirement~~. The silt soil~~s is~~ also has ~~the~~ high content of organic matter. The soil in the study plots was categorized as acidic soil, indicated by the pH ~~(H_2O) and pH (KCl)~~ values of lower than 5 and the low content of organic C, total N, P, and K. Fine soil grains ~~is~~ usually tend to have high erosion risk because they do not form ~~a~~ stable soil structures easily because of the fragile cohesion between their particles (A'Yunin 2008).

Table 6. Rainfall, surface runoff volume, and eroded soil mass in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system ~~o~~in the two different slope classes

Rain	Rainfall	Surface runoff (liter)	Eroded soil mass (gram/30 m^2)

event	(mm)	Steep slope (>25-45%)	Very steep slope (>45%)	Steep slope (>25-45%)	Very steep slope (>45%)
1	74	46.74	43.40	128.76	111.59
2	37	12.21	46.74	39.93	631.4
3	14	7.87	46.74	13.51	149.74
4	20	7.87	46.74	9.22	164.05
5	41	46.74	46.26	119.22	348.13
6	21	14.95	47.21	47.72	214.6
7	36	46.74	46.74	62.95	147.84
8	22	15.74	46.74	32.75	115.41
9	7	4.72	7.79	4.96	25.43
10	15	6.30	46.74	11.06	97.29
11	13	6.23	15.74	6.49	105.87
12	22	23.37	47.21	14.31	75.35
13	31	46.74	47.21	32.43	61.04
14	49	11.8	46.74	18.12	96.33
15	10	6.3	47.21	2.8	57.23
16	10	6.3	17.92	2.03	15.36
17	17	7.87	46.74	2.07	22.89
18	5	8.66	30.69	0.7	24.18
19	9	4.72	31.48	0.38	8.9
20	14	7.87	46.74	0.16	15.26
21	28	7.87	46.74	2.07	34.34
22	41	14.16	47.21	1.14	14.31
23	42	37.77	47.21	3.05	35.29
24	21	11.02	47.21	1.11	25.75
25	27	11.80	46.74	0.72	16.21
26	10	7.87	47.21	0.16	11.45
27	45	15.74	47.21	0.32	8.58
Total	681	445.92	1132.26	558.13	2633.81
Average	25	16.52	41.94	20.67	97.55

The evaluation of erosion hazard index, erosion hazard class, and erosion hazard level could be used as an indicator to determine the erosion status in the area. The hydro-orological parameters recorded in this study are shown in Table 7. The tolerable erosion rate for sloping lands is 25 ton ha^{-1}year^{-1} at a soil depth of more than 100 cm (Rahim 1995). The erosion rate of both steep slope and very steep slope plots were less than 15 ton ha^{-1}year^{-1} while the soil depth in the plot was more than 90 cm. The potential erosion rates in steep slope and very steep slope in studied plots were 0.38 ton ha^{-1}year^{-1} and 1.31 ton ha^{-1}year^{-1}, respectively. The erosion hazard index ~~of~~was 0.03 (low) and 0.13 (low) ~~were evaluated in~~for steep slope and very steep slope plots, respectively. The erosion hazard classes (class I) and erosion hazard level ~~o~~in both studied slopes ~~were classified~~belong to "very low" category.

~~The hydro-orological parameters in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system on the two different slope classes are shown in Table 7.~~ The soil erosion rates recorded ~~of agroforestry system of *F. moluccana* and *V. cylindrica* on different slope lands~~ in the current study ~~site~~ was lower than the values reported ~~ose application of~~for some other agroforestry systems (Karyati et al. 2018; Sarminah et al. 2018; Sumarno et al. 2011) as presented in Table 8. This result implied that the combination of vegetative (*F. moluccana* and *V. cylindrica*) and terrace system could be effectively implemented in ~~the~~ different sloping lands.

Table 7. The hydro-orological parameters in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system ~~o~~in the two different slope classes

Slope gradient	Surface runoff rate (m^3 ha^{-1} year^{-1})	Potential erosion rate (ton ha^{-1} year^{-1})	Tolerable erosion rate (ton ha^{-1}year^{-1})	Erosion hazard index	Erosion hazard class	Erosion hazard level
>25-45%	305.77	0.38	25[1)]	0.03 (Low)	I (Very low)	Very low
>45%	776.41	1.81	25[1)]	0.13 (Low)	I (Very low)	Vey low

[1)]Soil depth in the study plot was >100 cm and the tolerable erosion rate for hills or slope lands was 25 ton ha^{-1}year^{-1} (Rahim 1995)

Table 8. ~~The~~Comparison of soil erosion reported in the current study with earlier reports for other ~~in the~~ agroforestry plantation systems

Planting system	Erosion (ton ha^{-1}year^{-1})	Location	Researcher (year)
Soil and water conservation technique and application of agroforestry system	190.08	Ngadipiro Village. Nguntoronadi Sub-district. Wonogiri District. Central Java. Indonesia	Sumarno et al. (2011)

Agroforestry system of *A. cadamba* and *Glycine max*		East Kalimantan. Indonesia	Karyati et al. (2018)
Slope of >15-25%	32.13		
Slope of >25-45%	52.51		
Agroforestry system of *F. moluccana* and *A. hypogaea*		East Kalimantan. Indonesia	Sarminah et al. (2018)
Slope of >15-25%	20.05		
Slope of >25-45%	45.50		
Agroforestry system of *F. moluccana* and *V. cylindrica*		East Kalimantan. Indonesia	ThisCurrent study
Slope of >15-25%	0.38		
Slope of >25-45%	1.81		

Economic aspects

The implementation of vegetative (*F. moluccana-V. cylindrica*) and terrace system in different slope classes needsinvolves the cost expenditure to buy planting and other materials., depreciation ofn equipments. and wages of labor. Besides cost expenditure. ThisOn the other hand, implemeantation of this method gives revenue and profit, especially from *V. cylindrica* yield. Table 9 shows economic analysis of *V. cylindrica* as intercropping in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system oin the two different slope classes. The material cost was used toinvolved were for buying *F. moluccana* seedlings., *V. cylindrica* seeds, NPK fertilizer, pesticides., plastic strings., gunny sacks,, and fertilizers from animal. Fertilizer is given to increase soil fertility. The profit of *F. moluccana-V. cylindrica* plantation in steep slope was Rp 3,,8,65,000.00 ha^{-1} cs^{-1} and in very steep slope was Rp 6,65,000.00 ha^{-1} cs^{-1}. This profit was resulted from selling the yield from *V. cylindrica* yield.

The profit offrom *V. cylindrica* yield in steep slope was higher than *A. hypogaea* yield on agroforestry system of *F. moluccana-A. hypogaea* as reported by Karmini et al. (2017). The total cost, total revenue, and profit onrelated to agroforestry system of *F. moluccana* and *A. hypogaea* agroforestry system wereas Rp 10,985,000 ha^{-1} cs^{-1}, Rp 14,000,000 ha^{-1} cs^{-1} and Rp 3,015,000 ha^{-1} cs^{-1}. However, implementation of growing *V. cylindrica* as intercropping in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system oin the two different slope classeslands is highlystill give benefitial when compared to growing *G. max* yield onin agroforestry system *A. cCadamba - G. Mmax* agroforestry system. Karmini et al. (2017) analyzedreported that growing *G. max* in *A. cCadamba - G. max* agroforestry system that theinvolved total cost of Rp 11,019,000.00 ha^{-1} cs^{-1}, total revenue ofwas Rp 3,500,000 ha^{-1} cs^{-1}, and the profit ofwas Rp (-)7,519,000.00 ha^{-1} cs^{-1} .are from *G. max* yield on agroforestry system *A. cadamba-G. max*. The application vegetative (*F. moluccana-V. cylindrica*) and terrace system in different slope classes could add economic values for short term. For long term, *F. moluccana* is also increase added value, especially soil and water conservation.

Table 9. Economic analysis of growing *V. cylindrica* as intercropping in vegetative (*F. mMoluccana - V. cylindrica*) and terrace combination system oin the two different slope classes

Sl. No.	CostItem/activity	Quantity	Unit	Price (Rp)	Total (Rp. ha^{-1}cs^{-1})
Production cost					
Material cost					
1	*F. moluccana* seedlings	1,350.00	units ha^{-1}	3,000.00	4,050,000.00
2	*V. cylindrica* seeds	350.00	units ha^{-1} cs^{-1}	15,000.00	5,250,000.00
3	NPK fertilizer	100.00	kg ha^{-1} cs^{-1}	15,000.00	1,500,000.00
4	Pesticides	25.00	kg ha^{-1} cs^{-1}	30,000.00	750,000.00
5	Plastic strings	1.00	units ha^{-1} cs^{-1}	30,000.00	30,000.00
6	Gunny sacks	20.00	units ha^{-1} cs^{-1}	2,000.00	40,000.00
7	Fertilizer from animal	50.00	units ha^{-1} cs^{-1}	25,000.00	1,250,000.00
	Sub total				12,870,000.00
Depreciation cost					
8	Hoe	2.00	units ha^{-1}	125,000.00	20,833.33
9	Chopper	2.00	units ha^{-1}	100,000.00	16,666.67
10	Sickle	2.00	units ha^{-1}	60,000.00	10,000.00
11	Sprayer	1.00	units ha^{-1}	350,000.00	17,500.00
	Sub total				65,000.00
Labor cost					

Formatted: Font: Not Italic

Formatted: Font: Not Italic

Formatted: English (United States)

Formatted: English (United States)

Formatted: English (United States)

Formatted: English (United States)

Formatted: English (United States)

12	Land preparation	7.00	days ha^{-1} cs^{-1}	100,000.00	700,000.00
13	Planting	6.00	days ha^{-1} cs^{-1}	100,000.00	600,000.00
14	Fertilizing	4.00	days ha^{-1} cs^{-1}	100,000.00	400,000.00
15	Weeding	5.00	days ha^{-1} cs^{-1}	100,000.00	500,000.00
16	Pest and disease~~s~~ controlling	4.00	days ha^{-1} cs^{-1}	100,000.00	400,000.00
17	Harvesting	6.00	days ha^{-1} cs^{-1}	100,000.00	600,000.00
	Sub total				3,200,000.00
Total cost					16,135,000.00
Total revenue from *V. cylindrica*					
	Steep slope plot (>25-45%)	2,500.00	kg ha^{-1}	8,000.00	20,000,000.00
	Very steep slope plot (>45%)	2,100.00	kg ha^{-1}	8,000.00	16,800,000.00
Profit		Steep slope plot (>25-45%)			3~~,~~8,65,000.00
		Very steep slope plot (>45%)			6,65,000.00

Note: cs = cropping season

The implementation of a combination of vegetative and terrace system ~~combination in~~for soil and water conservation could be appl~~y~~ied in the different slope lands. This ~~application~~practice will ~~give~~be benefitial based on silvicultural, hydro-orologica~~l~~l, and economic aspects.~~ The combination vegetative and civil technique still shows good growth paramaters. The hydro-orological parameters in this implementation is hoped can reduce surface runoff rate and erosion rate.~~ The short term –economic benefit ~~will be given~~is provided by agricultural yield ~~as~~ from the crop~~ping~~ plant~~ in the short term~~. In long term, this ~~application~~practice is beneficial in terms of ~~will give~~ soil and water conservation and environment aspects. The ~~important~~ information of this study on silvicultural, hydro-orological~~,~~ and economic aspects could be used for ~~basic~~ recommend~~ation~~ing ~~in relation to~~ alternative agroforestry systems ~~for~~in small scale, and soil conservation programs ~~for~~ in a wide scale. ~~The basic data could be used as consideration by~~for all stakeholders~~,~~ including farmers, foresters, private parties and the ~~goverment~~governmental agencies ~~in terms of~~concerned with land management and soil conservation activities.

ACKNOWLEDGEMENTS

The authors wish to express~~ed our~~their thanks to Ministry of Research, Technology and Higher Education, Republic of Indonesia for supporting *Hibah Penelitian Strategis Nasional Institusi*.

REFERENCES

ADB. 2016. Indonesia Country Water Assessment. Manila. (PATA 8432-INO). ADB, Mandaluyong City, Philippines.
A'Yunin Q. 2008 Prediksi Tingkat Bahaya Erosi dengan Metode USLE di Lereng Timur Gunung Sindoro. Skripsi. Universitas Sebelas Maret. Surakarta.
Budiastuti S. 2013. Sistem agroforestri sebagai alternatif hadapi pergeseran musim guna pencapaian keamanan pangan. Ekosains 5 (1): 1-5.
Caliskan S, Arslan M, Uremis I, Caliskan ME. 2007. The effects of row spacing on yield and yield components of full season and double-cropped soybean. Turk J Agric For 31: 147-154.
Chaplot V, LeBissonnais Y. 2000. Field measurements of interrill erosion under different slopes and plot sizes. Earth Surf Proces Landf 25: 145-153.
Edison, Bisri M, Suhartanto E. 2012. Studi teknologi konservasi untuk menurunkan laju erosi pada Sub DAS Sombe Lewara Provinsi Sulawesi Tengah. Jurnal Teknik Pengairan 3(2): 204–210.
Hammer WI. 1981. Second soil conservation consultant report. AGOF/INS/78/006. Tech. Note No. 10. Centre for Soil Research, Bogor.
~~Indrayati A. 2013. Peningkatan ketahanan terhadap risiko bencana melalui pendidikan konservasi lahan berbasis masyarakat di dataran tinggi Dieng. Jurnal Geografi 10(2): 154-166.~~
Karmini, Sarminah S, Karyati. 2017. Economic analysis of groundnut (*Arachis hypogaea*) and soybean (*Glycine max*) as intercropping plants in two agroforestry systems. Biodiversitas 18 (2): 483-493.
Karyati. 2015. Pengaruh iklim terhadap jumlah kunjungan wisata di Kebun Raya Unmul Samarinda (KRUS). Jurnal Riset Kaltim 3(1): 51-59.
Karyati, Ardianto S. 2016. Dinamika suhu tanah pada kedalaman berbeda di Hutan Pendidikan Fakultas Kehutanan Universitas Mulawarman. Jurnal Riset Kaltim 4 (1): 1-12.
Karyati, Ardiyanto S, Syafrudin M. 2016. Fluktuasi iklim mikro di Hutan Pendidikan Fakultas Kehutanan Universitas Mulawarman. Agrifor 15(1): 83-92.
Karyati, Sarminah S, Karmini, Simangunsong G, Tamba J. 2018. The mixed cropping of *Anthocephalus cadamba* and *Glycine max* for rehabilitating sloping lands. Biodiversitas 19(6): 2088-2095
Kjeldahl J. 1883. New method for the determination of nitrogen. Chem. News 48(1240): 101–102.
KRUS. 2013. Laporan Tahunan Kebun Raya Unmul Samarinda (KRUS) Tahun 2013. KRUS, Samarinda.
KRUS. 2014. Laporan Tahunan Kebun Raya Unmul Samarinda (KRUS) Tahun 2014. KRUS, Samarinda.
Mardaeni, Munir A, Useng D. 2014. Skenario penggunaan lahan untuk mereduksi erosi Berbasis Fuzzy Multi Attribute Decision Making Di DAS Jeneberang J. Sains & Teknologi, 14(3): 277–284.
Matatula J. 2009. Upaya rehabilitasi lahan kritis dengan penerapan teknologi agroforestry sistem silvopastoral di Desa Oebola Kecamatan Fatuleu Kabupaten Kupang. Inotek 13(1): 63-74.

Formatted: Highlight

Ministry of Agriculture Republic of Indonesia. 2018. Agricultural Statistics 2018. Ministry of Agriculture Republic of Indonesia, Jakarta.

Purnamasari DA, Surjandari NS, As'ad S. 2014. Desain terasering pada lereng Sungai Gajah Putih Surakarta. Jurnal Matriks Teknik Sipil 2(1): 151-161.

Rahim SE. 1995. Erosi Tanah dan Pemodelan Pendugaannya dalam Dinamika Lingkungan Hidup Sumatera Selatan. PPLH Lembaga Penelitian Universitas Sriwijaya.

Regulation of Ministry of Forestry Republic of Indonesia, Ministry of Forestry Republic of Indonesia Number: P.60/Menhut-II/2009.

Regulation of Directorate General of Watershed Management and Social Forestry, Ministry of Forestry Republic of Indonesia Number: P.4/V-SET/2013.

Sarminah S, Karyati, Karmini, Simbolon J, Tambunan E. 2018. Rehabilitation and soil conservation of degraded land using sengon (*Falcataria moluccana*) and peanut (*Arachis hypogaea*) agroforestry system. Biodiversitas 19 (1): 222-28.

Slavin SL. 2009. Economics. McGraw-Hill Irwin, New York.

Sumarno, Winarno J, Prastomo I. 2011. Kajian pengelolaan lahan berdasarkan tingkat bahaya erosi dan pola konservasi tanah dan air di Desa Ngadipiro Kecamatan Nguntoronadi, Kabupaten Wonogiri. Sains Tanah-Jurnal Ilmu Tanah dan Agroklimatologi 8 (1): 13-22.

Swestiani D, Purwaningsih S. 2013. Production of groundnut (*Arachis hypogaea* L.) in agroforestry based sengon and manglid timbers. Agroforestry 1(2): 71-82.

Statistics of East Kalimantan Province. 2018. Kalimantan Timur Province in Figure 2018. BPS Statistics of East Kalimantan Province, Samarinda.

Statistics of Indonesia. 2018. Indonesia in number 2017. Jakarta: Statistics of Indonesia.

Tala'ohu SH, Al-Jabri M. 2008. Mengatasi degradasi lahan melalui aplikasi pembenah tanah. Jurnal Zeolit Indonesia 7(1): 22-34.

Wahyu I, Pranoto H, Supriyanto B. 2018. Kajian produktivitas tanaman semusim pada sistem agroforestri di Kecamatan Samboja Kabupaten Kutai Kartanegara. Agroekoteknologi Tropika Lembab 1(1): 24-33.

Wahyudi, Panjaitan S. 2013. Perbandingan sistem agroforestri, monokultur intensif, dan monokultur konvensional dalam pembangunan hutan tanaman sengon. Prosiding Seminar Nasional Agroforestri 165-171.

Walkley A, Black IA. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science 37: 29-38.

Formatted: Highlight

Formatted: Highlight

Formatted: Indent: Left: 0", Hanging: 0.2"

BIODIVERSITAS
Volume 20, Number 8, August 2019
Pages: xxxx

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d2008xx

Silvicultural, hydro-orological and economic aspects of a combination of vegetative (*Falcataria moluccana-Vigna cylindrica*) and terrace systems in soils of different slopes

Commented [a1]: Naskah ini terlalu banyak menggunakan pustaka dalam bahasa Indonesia. Mohon dikurangi. Sebaiknya naskah referensi selain bahasa Inggris maksimum 10%

KARYATI[1,♥], SRI SARMINAH[1], KARMINI[2,♥♥], RUJEHAN[1], VEBI FITRIANA EKO LESTARI[1], WENDY SATRIA PANORAMA[1]

[1]Faculty of Forestry, Mulawarman University, Gunung Kelua Campus, Jalan Ki Hajar Dewantara, Samarinda, East Kalimantan, Indonesia 75119 Phone. +62-541-35089 Fax. +62-541-732146, ♥email: karyati@fahutan.unmul.ac.id, karyati.hanapi@yahoo.com

[2]Faculty of Agriculture, Mulawarman University, Gunung Kelua Campus, Jalan Pasir Balengkong, Samarinda, East Kalimantan, Indonesia 75119, ♥♥email: karmini@faperta.unmul.ac.id, karmini.kasiman@yahoo.com

Manuscript received: 12 July 2019. Revision accepted: xxx July 2019.

Abstract. *Karyati, Sarminah S, Karmini, Rujehan, Lestari VFE, Panorama WS. 2019. Silvicultural, hydro-orological and economic aspects of a combination of vegetative (*Falcataria moluccana-Vigna cylindrica*) and terrace systems in soils of different slopes. Biodiversitas 20: xxxx.* Soil and water conservation techniques involving a combination of vegetative and mechanical systems will increase the benefits from both consevation aspect as well as economic aspect. This study was aimed at analyzing the silvicultural, hydro-orological and economic aspects of a combination of vegetative (*Falcataria moluccana - Vigna cylindrica*) and terrace system in soils of different slopes (a steep and a very steep slope gradient). The silvicultural parameters examined in this study were the ground coverage of *V. cylindrica* growth and survival rate, stem diameter and height of *F. moluccana* trees. The hydro-orological parameters included erosion rate, erosion hazard index, erosion hazard class and erosion hazard level. The economic parameters included total cost, total revenue and profit. The result showed that the survival rate , diameter increment and height increment of *F. moluccana,* and ground coverage of *V. cylindrica* in the land with the steep slope (>25-45%) was 90%, 2.02 cm year^{-1}, 1.54 m year^{-1}, and 80-90%, respectively. The erosion rate, erosion hazard index, erosion hazard class, and erosion hazard level in this steep slope was 0.38 ton ha year^{-1}, 0.03 (low), I (very low), and very low, respectively. In the steeper ground (>45%), the survival rate of *F. moluccana* reached 90%, the *V. cylindrica* coverage was 70-79% and the diameter and height increment of *F. moluccana* was 1.63 cm year^{-1} and 1.19 m year^{-1}, respectively. The erosion rate was 1.81 ton ha^{-1} year^{-1}, erosion hazard index of 0.13 (low), erosion hazard class was I (very low), and erosion hazard level was low in the very steep slope land. The profit from *V. cylindrica* was Rp 3,865,000.00 ha^{-1} cropping season^{-1} and Rp 665,000.00 ha^{-1} cropping season^{-1} in steep slope and very steep slope, respectively. The application of the proposed combination of vegetative and terrace system could reduce surface run off and erosion rate in the long term, in addition to providing short term economic benefits.

Keywords: Economic, hydro-orological, silvicultural, slope, terrace

INTRODUCTION

The over exploitation of natural resources which has exceeded the carrying capacity, coupled with population pressure on land resourcess, will lead to an increase in degraded land area. In Indonesia, 78 million ha area of land has been catagorized as degraded land, of which, 48 million ha is slightly degraded area, 23 million ha is moderately degraded area and 7 million ha is highly degraded area (ADB 2016). The degraded areas are caused by biophysical, social, economical and cultural factors (Matatula 2009). One way to increase the quality of degraded land is by using soil conditioners, combined with soil and water conservation techniques, organic matter management and appropriate fertilization based on soil analysis and plant requirement (Tala'ohu and Al-Jabri 2008). The application of cultivation techniques in the marginal and sloping lands has to be combined with the integrated environmental factors (Budiastuti 2013). The policy concept that was found to reduce erosion rate in watershed and sedimentation in reservoir is terrace and crop rotation system (Mardaeni et al. 2014). Edison et al. (2012) recommended vegetative land conservation technology to conserve cultivation land (*tegalan*), perennial plants in upstream area of *tegalan* and plantations in downstream area.

The mixed cropping of sengon *(Falcataria moluccana)* and peanut (*Arachis hypogaea*) as well as jabon *(Anthocephalus cadamba)* and soybeans (*Glycine max*) could be implemented in different soil slopes for rehabilitating and soil conservation in sloping lands, based on the growth and hydro-orological parameters (Karyati et al. 2018; Sarminah et al. 2018). These two agroforestry systems of *F. moluccana - A. hypogaea* and *A. cadamba - G. max* are feasible and applicable to rehabilitate and conserve the critical lands. Although planting of *G. max* was not profitable in some critical lands, the agroforestry system of *A.cadamba* and *G. max* still had many benefits from the aspect of ecology and conservation for long terms (Karmini et al. 2017). The production, harvested area, and productivity of *Vigna cylindrica* (long beans) in Indonesia in 2017 was 381,185 ton; 56,111 hectare, and 6.79 ton hectare^{-1}, respectively (Ministry of Agriculture Republic of Indonesia 2018; Statistics of Indonesia 2018). In East Kalimantan, the production of *V. cylindrica* in 2017 was 71,456 quintal, while harvested area and productivity was 1,361 hectare and 52.50 quintal hectare^{-1}. The productivity of *V. cylindrica* in Samarinda in 2017 was 26.86 quintal hectare^{-1}, total production was 3,089 quintal and the harvested area of 115 hectare (Ministry of Agriculture Republic of Indonesia 2018; Statistics of East Kalimantan Province 2018).

The total land area of Samarinda City of East Kalimantan Province is 71.800,00 ha, out of which land area with less than 2% slope is 27.39%, 2-15% slope is 25.47%, 15-25% slope is14.81%, 25-40% slope is 15.67%, and more than 40% slope is 13.02% (Statistics of East Kalimantan Province 2018). A combination of vegetative and terrace techniques of soil and water conservation may be the appropriate choice to rehabilitate sloping lands based on silvicultural, hydro-orological and economic aspects. The plantations of forestry plants is hoped to provide silvicultural, conservation and economic values in a long term program. On the other hand, planting of agricultural plants is expected to provide short term economic benefits. The objectives of this study were to investigate silvicultural, hydro-orological and economic aspects of implementation of a combination of vegetative (*F. moluccana*-*V. cylindrica*) and terrace systems in different soil slopes, ranging from steep to very steep slope gradients.

MATERIALS AND METHODS

Study area

This study was conducted in Educational Forest of Forestry Faculty of Mulawarman University, Lempake District, Samarinda City, East Kalimantan Province. The study duration was six months, from January to June 2018. The experimental forest covered a total area of 300 ha and was located at 0°25'10"–0°25'24" South latitude and 117°14'00"–117°14'14" East longitude, in between kilometers 10 and 13 of the Samarinda-Bontang Highway. Administratively, this experimental forest is situated in Tanah Merah Village, North Samarinda District, Samarinda City, East Kalimantan Province (KRUS 2013; KRUS 2014).

The study area received 211.5 mm monthly average rainfall, average air temperature is 27.4^{0}C, and relative humidity was 82.2% (Karyati 2015). The average daily temperature and relative humidity inside the forest ranged from 23.7°C to -30.9°C and 81.4% t0 99.3%, respectively. The average daily temperature and relative humidity outside the forest was 25.9°C-28.8°C and 76.0%-90.0%, respectively. The daily average light intensity ranged from 1.08 µmol to 18.41 µmol (Karyati and Ardianto 2016). The climate of Samarinda City was classified as type A climate (a quotient (Q) of 4.8 per cent) based on Schmidt and Ferguson (1951) system which is characterized by highly humidity with a tropical rainforest vegetation (Karyati et al. 2016).

Procedures

Experimental procedures

Experiments were conducted in two 10 m x 10 m experimental plots which were located in areas with two different slope classes inside the experimental forest. One of these two experimental plots had a steep slope (>25-45%) and other had a very steep slope (>45%).

2 m wide terraces were made in each experiental plot. Terrace was completed by ditches sized 25 cm wide and 10 cm depth. Sengon (*F. moluccana*) and long beans (*V. cylindrica*) were planted on both plots. *F. moluccana* trees were planted with a spacing of 3 m × 3 m. *V. cylindrica*, as the intercrop legume, was grown in between the sengon trees. Two erosion measurement plots of 10 m × 3 m size were placed in each of the two experimental plots. The growth paremeters were measured once in every month, for four months period. Plants were maintained by regular watering, weeding, fertilizer application, and pest and disease control. For economic evaluation, only the long beans were harvested, but not the sengon trees. The measurement of hydro-orological parameters were conducted during 27 times rain events.

Analysis of soil properties

The analysis of soil physicochemical properties, such as pH, C organic, total N, P, K, and soil texture, were conducted in Laboratory of Soil Science, Tropical Forest Research Center, Mulawarman University. Soil pH was determined in distilled water and 1 N KCl in a soil to solution ratio of 1:2.5 by the glass electrode method. The C organik and total nitrogen (total N) were analyzed using Walkley and Black method (1934) and Kjeldahl method (1883), respectively. Soil P and K were analyzed using Bray 1 method (1954).

Data analysis

Silvicultural parameters

The observation and measurement of plant growth was conducted at the end of every month for four months. The observation was carried out on both *F. moluccana* and *V. cylindrica* plants. The parameters studied for *F. moluccana* were plant survival rate, tree height, and stem diameter. For *V. cylindrica*, ground coverage and yield was recorded. The plant health was measured for both *F. moluccana* and *V. cylindrica*. A healthy plant was characterized as a plant with a normal height, fresh green leaves, normal stem, and no disease/pests and weed (Ministry of Forestry Republic of Indonesia 2009).

Hydro-orological parameter

The hydro-orological parameters measured in this study were surface runoff, potential soil erosion rate, erosion hazard index, erosion hazard class, and erosion hazard level (Hammer 1981). The erosion hazard index categories and erosion hazard level classification are shown in Table 1 and Table 2, respectively. The erosion hazard index is determined as potential erosion rate (ton ha^{-1} year^{-1}) divided by tolerable erosion rate (ton ha^{-1} year^{-1}) (Hammer 1981).

Economic analysis

In this study, the analyzed economic aspects were cost, revenue and profit from long beans as intercropping in sengon (long beans) agroforestry systems. Cost is calculated from price and quantity of inputs, revenue is the price of produced yield, and profit is revenue minus cost (Slavin 2009).

RESULTS AND DISCUSSION

Silvicultural aspects

The recorded plant growth parameters of *F. moluccana* and *V. cylindrica* for the two different slope classes are summarized in Table 3. The growth of *F. moluccana* and *V. cylindrica* combination were "moderate" to "very good" in the steep slope and very steep slope. The survival rate of *F. moluccana* in both slope classes wwas "very good" (90%). The ground coverage of *V. cylindrica* in steep slope was better (80-89%) than in very steep slope (70-79%). Meanwhile, the yield of *V. cylindrica* was also higher (2,500 kg ha^{-1}) in steep slope when compared to the yield in very steep slope (2,100 kg ha^{-1}).

The average of *V. cylindrica* yield in this study was almost similar to the average of Samarinda's yield, but lower than East Kalimantan and Indonesia's yield (Statistics of East Kalimantan Province 2018; Statistics of Indonesia 2018). However, *V. cylindrica*'s yield obtained in this study was lower than reported by Wahyu et al. (2018). Wahyu et al. (2018) reported that the productivity of *V. cylindrica* in Samboja Subdistrict, Kutai Kartanegara District, East Kalimanatn Province was 7,010 kg ha^{-1} and 13,640 kg ha^{-1} from monoculture and agroforestry systems, respectively.

The monthly diameter and height increments of *F. moluccana* trees, measured for four months, are provided in Tables 4 and 5. The stem diameter and height increment of *F. moluccana* trees is faster in the slightly steep slope than in the highly steeper slope. The average stem diameter and height increments of *F. moluccana* were 2.02 cm $year^{-1}$ and 1.54 m $year^{-1}$ in the steep slope, and 1.63 cm $year^{-1}$ and 1.19 m $year^{-1}$, in very steep slope.

The average diameter increment of *F. moluccana* in *F. moluccana* and *V. cylindrica* agroforestry system (on steep and very steep slopes) was lower than those in *F. moluccana* and *Arachis hypogaea* agroforestry system (on slight steep and steep slopes) as reported by Sarminah et al. (2018). On the contrary, the average height increment of this combination was higher than those reported by Sarminah et al. (2018). Similarly, the diameter increment of *F. moluccana* in this study was also lower than those in agroforestry system, monoculture system, and intensive monoculture system (Swestiani and Purwaningsih 2013; Wahyudi and Panjaitan 2013). However, the average diameter increments of *F. moluccana* trees on the steep slope was higher than those planted in the conventional monoculture system (Wahyudi and Panjaitan 2013).

Hydro-orological aspects

The hydro-orological aspects were determined by surface runoff and eroded soil mass. Table 6 presents data regarding rainfall, eroded soil mass, and surface runoff volume in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system in the two different slope classes. The result showed that the higher rainfall results in surface runoff and eroded soil mass. Several factors such as rainfall, slope, cover crop, and management practices have suspected influence on soil erosion in the study sites. The length and gradient of slope influences soil erosion. In the steeper slope lands, the rainfall tend to transport the soil particles into lower area faster. It will increase surface runoff and eroded soil mass as well erosion rate. The increasing slope and rain intensity have increased the runoff rate from 20% to 90% (Chaplot and LeBissonnais 2000).

Table 1. Erosion hazard index categories

Erosion hazard index	Category
< 1.00	Low
1,01-4,00	Moderate
4,01-10,00	High
> 10,01	Very high

Source: Hammer (1981)

Table 2. Erosion hazard level classification

Soil column (cm)	Erosion class				
	I	II	III	IV	V
	Erosion rate (ton ha^{-1} $year^{-1}$)				
	<15	15-<60	60-<180	180-480	>480
Deep (>90)	Very low 0	Low I	Moderate II	Heavy III	Very heavy IV
Intermediate (60-90)	Low I	Moderate II	Heavy III	Very high IV	Very heavy IV
Shallow (30-<60)	Moderate II	Heavy III	Very heavy IV	Very heavy IV	Very heavy IV
Very shallow (<30)	Heavy III	Very heavy IV	Very heavy IV	Very heavy IV	Very heavy IV

Source: Regulation of Directorate General of Watershed Management and Social Forestry, Ministry of Forestry Republic of Indonesia (2013). Note: 0=Very low; I=Low; II=Moderate; III=Heavy; IV=Very heavy

Table 3. The growth parameters of *F. moluccana* and *V. cylindrica* in the two different slope classes

Plant species	Steep slope (>25-45%)				Very steep slope (>45%)			
	Healthy plants (%)	Survival rate (%)	Ground coverage (%)	Yield (kg ha^{-1})	Healthy plants (%)	Survival rate (%)	Ground coverage (%)	Yield (kg ha^{-1})
F. moluccana	90 (Very good)	90 (Very good)	-	-	90 (Very good)	90 (Very good)	-	-
V. cylindrica	80-89 (Good)	-	80-89 (Good)	2,500	70-79 (Moderate)	-	70-79 (Moderate)	2,100

Table 4. *Falcataria moluccana* stem diameter increments (mm) in the two different slopes classes

Tree number	Steep slope (>25-45%)					Very steep slope (>45%)				
	D_0	d_1	d_2	d_3	d_4	D_0	d_1	d_2	d_3	d_4
1	12.10	12.85	14.15	16.15	18.68	14.40	15.00	16.05	18.25	21.10
2	9.25	10.00	11.25	12.80	15.00	6.20	6.95	7.90	9.25	11.00
3	8.20	8.90	10.10	11.65	13.85	9.10	9.70	11.00	12.95	15.50
4	5.10	7.80	9.05	10.60	12.50	9.70	10.20	11.25	12.75	15.10
5	12.70	13.65	14.95	16.90	19.25	11.10	11.65	12.90	14.85	17.35
6	8.60	9.55	11.00	12.70	14.75	6.75	7.35	8.30	9.60	11.25
7	5.30	8.00	9.20	10.90	13.00	6.60	7.30	8.40	9.85	11.70
8	7.40	8.15	9.40	11.05	13.00	6.40	7.00	7.95	9.40	11.15
9	10.30	10.90	12.05	13.55	15.50	8.40	9.00	9.95	11.30	13.00
10	10.10	10.80	12.20	13.90	16.10	10.40	11.10	12.15	14.05	16.45
11	5.70	8.50	9.75	11.40	13.55	8.20	8.85	9.80	11.15	12.90
12	10.30	11.20	12.45	14.20	16.60	9.10	10.00	11.50	13.30	15.65
13	11.40	12.10	13.40	15.55	18.20	7.10	7.75	8.80	10.30	12.05
14	6.30	9.10	10.20	12.05	14.15	10.35	11.00	12.20	13.70	15.65
15	10.80	11.50	12.90	14.95	17.55	7.25	8.00	9.10	10.50	12.20
16	4.15	8.75	9.75	11.55	13.65	14.40	15.15	16.50	18.29	20.19
Mean	8.61	10.11	11.36	13.12	15.33	9.09	9.75	10.86	12.47	14.52
SD	2.69	1.81	1.86	1.99	2.17	2.58	2.58	2.66	2.88	3.16
Annual diameter increment	20.18 mm $year^{-1}$ = 2.02 cm $year^{-1}$					Annual diameter increment: 16.27 mm $year^{-1}$= 1.63 cm $year^{-1}$				

Note: D_0 = initial stem diameter (diameter measurement at the beginning of experiment); d_1, d_2, d_3, d_4 = diameter at the end of the first, second, third, and fourth month after planting; SD=Standard Deviation

Table 5. *F. moluccana* height increments (cm) in the two different slopes

Tree number	Steep slope (>25-45%)					Very steep slope (>45%)				
	H_0	h_1	h_2	h_3	h_4	H_0	h_1	h_2	h_3	h_4
1	153	177	189	205	213	176	197	205	210	220
2	144	157	182	194	206	160	173	182	201	205
3	102	106	111	117	125	143	153	157	164	174
4	176	188	196	202	212	124	136	148	155	166
5	165	183	204	212	227	146	163	166	171	176
6	157	172	194	204	212	123	138	145	158	161
7	167	179	187	200	209	145	157	167	176	188
8	146	167	183	192	204	151	165	178	182	194
9	182	205	219	231	242	146	162	166	175	181
10	184	197	208	219	231	164	177	186	199	206
11	116	131	143	159	177	173	185	189	194	208
12	119	136	148	163	176	152	163	169	175	184
13	159	173	183	195	208	119	134	142	154	162
14	168	184	194	212	220	169	186	190	202	214
15	169	185	198	211	221	134	149	158	167	178
16	137	150	163	172	181	101	113	126	136	144
Mean	153	168	181	193	204	145	159	167	176	185
SD	24,10	26,21	27,59	28,10	28,03	21,03	22,03	20,79	20,69	21,48
Annual height increment	153.75 cm $year^{-1}$ =1.54 m $year^{-1}$					Annual height increment: 119.1 cm $year^{-1}$ =1.19 m $year^{-1}$				

Note: H_0 = initial tree height (height measurement at the beginning of experiment); h_1, h_2, h_3, h_4 = height at the end of the first, second, third, and fourth month after planting; SD=Standard Deviation.

Table 6. Rainfall, surface runoff volume, and eroded soil mass in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system in the two different slope classes

Rain event	Rainfall (mm)	Surface runoff (L)		Eroded soil mass (g/30 m^2)	
		Steep slope (>25-45%)	Very steep slope (>45%)	Steep slope (>25-45%)	Very steep slope (>45%)
1	74	46.74	43.40	128.76	111.59
2	37	12.21	46.74	39.93	631.4
3	14	7.87	46.74	13.51	149.74
4	20	7.87	46.74	9.22	164.05
5	41	46.74	46.26	119.22	348.13
6	21	14.95	47.21	47.72	214.6
7	36	46.74	46.74	62.95	147.84
8	22	15.74	46.74	32.75	115.41
9	7	4.72	7.79	4.96	25.43
10	15	6.30	46.74	11.06	97.29
11	13	6.23	15.74	6.49	105.87
12	22	23.37	47.21	14.31	75.35
13	31	46.74	47.21	32.43	61.04
14	49	11.8	46.74	18.12	96.33
15	10	6.3	47.21	2.8	57.23
16	10	6.3	17.92	2.03	15.36
17	17	7.87	46.74	2.07	22.89
18	5	8.66	30.69	0.7	24.18
19	9	4.72	31.48	0.38	8.9
20	14	7.87	46.74	0.16	15.26
21	28	7.87	46.74	2.07	34.34
22	41	14.16	47.21	1.14	14.31
23	42	37.77	47.21	3.05	35.29
24	21	11.02	47.21	1.11	25.75
25	27	11.80	46.74	0.72	16.21
26	10	7.87	47.21	0.16	11.45
27	45	15.74	47.21	0.32	8.58
Total	681	445.92	1132.26	558.13	2633.81
Average	25	16.52	41.94	20.67	97.55

Table 7. The hydro-orological parameters in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system in the two different slope classes

Slope gradient	Surface runoff rate (m^3 ha^{-1} year^{-1})	Potential erosion rate (ton ha^{-1} year^{-1})	Tolerable erosion rate (ton ha^{-1}year^{-1})	Erosion hazard index	Erosion hazard class	Erosion hazard level
>25-45%	305.77	0.38	25[1)]	0.03 (Low)	I (Very low)	Very low
>45%	776.41	1.81	25[1)]	0.13 (Low)	I (Very low)	Vey low

[1)]Soil depth in the study plot was >100 cm and the tolerable erosion rate for hills or slope lands was 25 ton ha^{-1}year^{-1} (Rahim 1995)

Table 8. Comparison of soil erosion reported in the current study with earlier reports for other agroforestry plantation systems

Planting system	Erosion (ton ha^{-1}year^{-1})	Location	Researcher (year)
Soil and water conservation technique and application of agroforestry system	190.08	Ngadipiro Village. Nguntoronadi Sub-district. Wonogiri District. Central Java. Indonesia	Sumarno et al. (2011)
Agroforestry system of *A. cadamba* and *Glycine max*		East Kalimantan. Indonesia	Karyati et al. (2018)
Slope of >15-25%	32.13		
Slope of >25-45%	52.51		
Agroforestry system of *F. moluccana* and *A. hypogaea*		East Kalimantan. Indonesia	Sarminah et al. (2018)
Slope of >15-25%	20.05		
Slope of >25-45%	45.50		
Agroforestry system of *F. moluccana* and *V. cylindrica*		East Kalimantan. Indonesia	Current study
Slope of >25-45%	0.38		
Slope of >45%	1.81		

Table 9. Economic analysis of growing *V. cylindrica* as intercrop in vegetative (*F. moluccana - V. cylindrica*) and terrace combination system in the two different slope classes

No.	Item/activity	Quantity	Unit	Price (Rp)	Total (Rp. $ha^{-1}cs^{-1}$)
Production cost					
Material cost					
1	*F. moluccana* seedlings	1,350.00	units ha^{-1}	3,000.00	4,050,000.00
2	*V. cylindrica* seeds	350.00	units ha^{-1} cs^{-1}	15,000.00	5,250,000.00
3	NPK fertilizer	100.00	kg ha^{-1} cs^{-1}	15,000.00	1,500,000.00
4	Pesticides	25.00	kg ha^{-1} cs^{-1}	30,000.00	750,000.00
5	Plastic strings	1.00	units ha^{-1} cs^{-1}	30,000.00	30,000.00
6	Gunny sacks	20.00	units ha^{-1} cs^{-1}	2,000.00	40,000.00
7	Fertilizer	50.00	units ha^{-1} cs^{-1}	25,000.00	1,250,000.00
	Sub total				12,870,000.00
Depreciation cost					
8	Hoe	2.00	units ha^{-1}	125,000.00	20,833.33
9	Chopper	2.00	units ha^{-1}	100,000.00	16,666.67
10	Sickle	2.00	units ha^{-1}	60,000.00	10,000.00
11	Sprayer	1.00	units ha^{-1}	350,000.00	17,500.00
	Sub total				65,000.00
Labor cost					
12	Land preparation	7.00	days ha^{-1} cs^{-1}	100,000.00	700,000.00
13	Planting	6.00	days ha^{-1} cs^{-1}	100,000.00	600,000.00
14	Fertilizing	4.00	days ha^{-1} cs^{-1}	100,000.00	400,000.00
15	Weeding	5.00	days ha^{-1} cs^{-1}	100,000.00	500,000.00
16	Pest and disease controlling	4.00	days ha^{-1} cs^{-1}	100,000.00	400,000.00
17	Harvesting	6.00	days ha^{-1} cs^{-1}	100,000.00	600,000.00
	Sub total				3,200,000.00
Total cost					16,135,000.00
Total revenue from *V. cylindrica*					
	Steep slope plot (>25-45%)	2,500.00	kg ha^{-1}	8,000.00	20,000,000.00
	Very steep slope plot (>45%)	2,100.00	kg ha^{-1}	8,000.00	16,800,000.00
Profit		Steep slope plot (>25-45%)			3,865,000.00
		Very steep slope plot (>45%)			665,000.00

Note: cs = cropping season

The implementation of vegetative and terrace system was hoped to reduce the potential soil erosion. Generally, the best recommendation for soil and water conservation technology was to combine the vegetative and mechanical systems because such combinations are usually best for reducing soil erosion and decreasing conservation cost in long term as well as increasing short term economical benefits. The *F. moluccana* trees and *V. cylindrica* play a role as cover crop in the sloping lands that could avoid destructive effect of ranfall. In addition, the application of terrace system could reduce surface runoff and increase water infiltration into the deeper soils. Terrace is used to change the slope geometry which become more flater. It is needed in order to improve sloping land stability (Purnamasari et al. 2014).

The erosion rate is also affected by soil properties, especially soil texture. The soil texture in the study site is silty loam that usually support the greatest diversity of plant life. The silt tends to be loaded with the soluble nutrients required by plants. The silt soil also has high content of organic matter. The soil in the study plots was categorized as acidic soil, indicated by the pH value of lower than 5 and the low content of organic C, total N, P, and K. Fine soil grains usually tend to have high erosion risk because they do not form stable soil structures easily because of the fragile cohesion between their particles (A'Yunin 2008).

The evaluation of erosion hazard index, erosion hazard class, and erosion hazard level could be used as an indicator to determine the erosion status in the area. The hydro-orological parameters recorded in this study are shown in Table 7. The tolerable erosion rate for sloping lands is 25 ton $ha^{-1}year^{-1}$ at a soil depth of more than 100 cm (Rahim 1995). The erosion rate of both steep slope and very steep slope plots were less than 15 ton $ha^{-1}year^{-1}$ while the soil depth in the plot was more than 90 cm. The potential erosion rates in steep slope and very steep slope in studied plots were 0.38 ton $ha^{-1}year^{-1}$ and 1.31 ton $ha^{-1}year^{-}$

^{1}, respectively. The erosion hazard index was 0.03 (low) and 0.13 (low) for steep slope and very steep slope plots, respectively. The erosion hazard classes (class I) and erosion hazard level in both studied slopes belong to "very low" category.

The soil erosion rates recorded in the current study was lower than the values reported for some other agroforestry systems (Karyati et al. 2018; Sarminah et al. 2018; Sumarno et al. 2011) as presented in Table 8. This result implied that the combination of vegetative (*F. moluccana* and *V. cylindrica*) and terrace system could be effectively implemented in different sloping lands.

Economic aspects

The implementation of vegetative (*F. moluccana-V. cylindrica*) and terrace system in different slope classes involves cost expenditure to buy planting and other materials, depreciation on equipments and wages of labor. On the other hand, implementation of this method gives revenue and profit, especially from *V. cylindrica* yield. Table 9 shows economic analysis of *V. cylindrica* as intercrop in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system in the two different slope classes. The material cost involved were for buying *F. moluccana* seedlings, *V. cylindrica* seeds, NPK fertilizer, pesticides, plastic strings, gunny sacks, and fertilizersto increase soil fertility. The profit of *F. moluccana-V. cylindrica* plantation in steep slope was Rp 3,865,000.00 ha^{-1} cs^{-1} and in very steep slope was Rp 665,000.00 ha^{-1} cs^{-1}. This profit was from selling the yield from *V. cylindrica*.

The profit from *V. cylindrica* yield in steep slope was higher than *A. hypogaea* yield on agroforestry system of *F. moluccana-A. hypogaea* as reported by Karmini et al. (2017). The total cost, total revenue and profit related to *F. moluccana* and *A. hypogaea* agroforestry system was Rp 10,985,000 ha^{-1} cs^{-1}, Rp 14,000,000 ha^{-1} cs^{-1} and Rp 3,015,000 ha^{-1} cs^{-1}. However, growing *V. cylindrica* as intercrop in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system in different slope lands is highly benefitial when compared to growing *G. max* in *A. cadamba - G. max* agroforestry system. Karmini et al. (2017) reported that growing *G. max* in *A. cadamba - G. max* agroforestry system involved total cost of Rp 11,019,000.00 ha^{-1} cs^{-1}, total revenue was Rp 3,500,000 ha^{-1} cs^{-1}, and the profit was Rp (-)7,519,000.00 ha^{-1} cs^{-1}.

The implementation of a combination of vegetative and terrace system for soil and water conservation could be applied in the different slope lands. This practice will be benefitial based on silvicultural, hydro-orologica, and economic aspects. The short term economic benefit is provided by agricultural yield from the crop plant. In long term, this practice is benefitial in terms of soil and water conservation and environment aspects. The information of this study on silvicultural, hydro-orological and economic aspects could be used for recommending alternative agroforestry systems in small scale, and soil conservation programs in a wide scale for all stakeholders including farmers, foresters, private parties and the governmental agencies concerned with land management and soil conservation activities.

ACKNOWLEDGEMENTS

The authors wish to express their thanks to Ministry of Research, Technology and Higher Education, Republic of Indonesia for supporting *Hibah Penelitian Strategis Nasional Institusi*.

Commented [a2]: Tambahkan nomor kontrak

REFERENCES

ADB. 2016. Indonesia Country Water Assessment. Manila. (PATA 8432-INO). ADB, Mandaluyong City, Philippines.

A'Yunin Q. 2008 Prediksi Tingkat Bahaya Erosi dengan Metode USLE di Lereng Timur Gunung Sindoro. [Skripsi]. Universitas Sebelas Maret. Surakarta. [Indonesian]

Bray RH. 1954. A nutrient mobility concept of soil-plant relationships. Soil Sci 78(1): 9–22.

Budiastuti S. 2013. Sistem agroforestri sebagai alternatif hadapi pergeseran musim guna pencapaian keamanan pangan. Ekosains 5 (1): 1-5. [Indonesian]

Chaplot V, LeBissonnais Y. 2000. Field measurements of interrill erosion under different slopes and plot sizes. Earth Surf Proces Landf 25: 145-153.

Edison, Bisri M, Suhartanto E. 2012. Studi teknologi konservasi untuk menurunkan laju erosi pada Sub DAS Sombe Lewara Provinsi Sulawesi Tengah. Jurnal Teknik Pengairan 3(2): 204–210. [Indonesian]

Hammer WI. 1981. Second soil conservation consultant report. AGOF/INS/78/006. Tech. Note No. 10. Centre for Soil Research, Bogor.

Karmini, Sarminah S, Karyati. 2017. Economic analysis of groundnut (*Arachis hypogaea*) and soybean (*Glycine max*) as intercropping plants in two agroforestry systems. Biodiversitas 18 (2): 483-493.

Karyati. 2015. Pengaruh iklim terhadap jumlah kunjungan wisata di Kebun Raya Unmul Samarinda (KRUS). Jurnal Riset Kaltim 3(1): 51-59. [Indonesian]

Karyati, Ardianto S. 2016. Dinamika suhu tanah pada kedalaman berbeda di Hutan Pendidikan Fakultas Kehutanan Universitas Mulawarman. Jurnal Riset Kaltim 4 (1): 1-12. [Indonesian]

Karyati, Ardiyanto S, Syafrudin M. 2016. Fluktuasi iklim mikro di Hutan Pendidikan Fakultas Kehutanan Universitas Mulawarman. Agrifor 15(1): 83-92. [Indonesian]

Karyati, Sarminah S, Karmini, Simangunsong G, Tamba J. 2018. The mixed cropping of *Anthocephalus cadamba* and *Glycine max* for rehabilitating sloping lands. Biodiversitas 19(6): 2088-2095.

Kjeldahl J. 1883. New method for the determination of nitrogen. Chem News 48(1240): 101–102.

KRUS. 2013. Laporan Tahunan Kebun Raya Unmul Samarinda (KRUS). Tahun 2013. KRUS, Samarinda. [Indonesian]

KRUS. 2014. Laporan Tahunan Kebun Raya Unmul Samarinda (KRUS) Tahun 2014. KRUS, Samarinda. [Indonesian]

Mardaeni, Munir A, Useng D. 2014. Skenario penggunaan lahan untuk mereduksi erosi Berbasis Fuzzy Multi Attribute Decision Making di DAS Jeneberang. J Sains & Teknologi 14(3): 277–284. [Indonesian]

Matatula J. 2009. Upaya rehabilitasi lahan kritis dengan penerapan teknologi agroforestry sistem silvopastoral di Desa Oebola Kecamatan Fatuleu Kabupaten Kupang. Inotek 13(1): 63-74. [Indonesian]

Ministry of Agriculture Republic of Indonesia. 2018. Agricultural Statistics 2018. Ministry of Agriculture Republic of Indonesia, Jakarta. [Indonesia]

Purnamasari DA, Surjandari NS, As'ad S. 2014. Desain terasering pada lereng Sungai Gajah Putih Surakarta. J Matriks Teknik Sipil 2(1): 151-161. [Indonesian]

Rahim SE. 1995. Erosi Tanah dan Pemodelan Pendugaannya dalam Dinamika Lingkungan Hidup Sumatera Selatan. PPLH Lembaga Penelitian Universitas Sriwijaya. [Indonesian]

Regulation of Ministry of Forestry Republic of Indonesia, Ministry of Forestry Republic of Indonesia Number: P.60/Menhut-II/2009. [Indonesian]

Regulation of Directorate General of Watershed Management and Social Forestry, Ministry of Forestry Republic of Indonesia Number: P.4/V-SET/2013. [Indonesian]

Commented [a3]: Tulisan "[Indonesian]" jangan dihapus, kecuali pustaka tersebut dihapis

Sarminah S, Karyati, Karmini, Simbolon J, Tambunan E. 2018. Rehabilitation and soil conservation of degraded land using sengon (*Falcataria moluccana*) and peanut (*Arachis hypogaea*) agroforestry system. Biodiversitas 19 (1): 222-228.

Schmidt FH, Ferguson JHA. 1951. Rainfall types based on wet and dry period ratios for Indonesia and western New Guinea. Kementrian Perhubungan Djawatan Meteorologi dan Geofisik, Verhandelingen No. 42.

Slavin SL. 2009. Economics. McGraw-Hill Irwin, New York.

Sumarno, Winarno J, Prastomo I. 2011. Kajian pengelolaan lahan berdasarkan tingkat bahaya erosi dan pola konservasi tanah dan air di Desa Ngadipiro Kecamatan Nguntoronadi, Kabupaten Wonogiri. Sains Tanah-Jurnal Ilmu Tanah dan Agroklimatologi 8 (1): 13-22. [Indonesian]

Swestiani D, Purwaningsih S. 2013. Produksi kacang tanah (*Arachis hypogaea* L.) pada agroforestri berbasis kayu sengon dan manglid. Jurnal Penelitian Agroforestri 1(2): 71-82. [Indonesian]

Statistics of East Kalimantan Province. 2018. Kalimantan Timur Province in Figure 2018. BPS Statistics of East Kalimantan Province, Samarinda. [Indonesian]

Statistics of Indonesia. 2018. Indonesia in number 2017. Jakarta: Statistics of Indonesia. [Indonesian]

Tala'ohu SH, Al-Jabri M. 2008. Mengatasi degradasi lahan melalui aplikasi pembenah tanah. J Zeolit Indonesia 7(1): 22-34. [Indonesian]

Wahyu I, Pranoto H, Supriyanto B. 2018. Kajian produktivitas tanaman semusim pada sistem agroforestri di Kecamatan Samboja Kabupaten Kutai Kartanegara. Agroekoteknologi Tropika Lembab 1(1): 24-33. [Indonesian]

Wahyudi, Panjaitan S. 2013. Perbandingan sistem agroforestri, monokultur intensif, dan monokultur konvensional dalam pembangunan hutan tanaman sengon. Prosiding Seminar Nasional Agroforestri 165-171. [Indonesian]

Walkley A, Black IA. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci 37: 29-38.

BIODIVERSITAS
Volume 20, Number 8, August 2019
Pages: xxxx

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d2008xx

Silvicultural, hydro-orological and economic aspects of a combination of vegetative (*Falcataria moluccana-Vigna cylindrica*) and terrace systems in soils of different slopes

KARYATI[1,♥], SRI SARMINAH[1], KARMINI[2,♥♥], RUJEHAN[1], VEBI FITRIANA EKO LESTARI[1], WENDY SATRIA PANORAMA[1]

[1]Faculty of Forestry, Mulawarman University, Gunung Kelua Campus, Jalan Ki Hajar Dewantara, Samarinda, East Kalimantan, Indonesia 75119 Phone. +62-541-35089 Fax. +62-541-732146, ♥email: karyati@fahutan.unmul.ac.id, karyati.hanapi@yahoo.com

[2]Faculty of Agriculture, Mulawarman University, Gunung Kelua Campus, Jalan Pasir Balengkong, Samarinda, East Kalimantan, Indonesia 75119, ♥♥email: karmini@faperta.unmul.ac.id, karmini.kasiman@yahoo.com

Manuscript received: 12 July 2019. Revision accepted: xxx July 2019.

Abstract. *Karyati, Sarminah S, Karmini, Rujehan, Lestari VFE, Panorama WS. 2019. Silvicultural, hydro-orological and economic aspects of a combination of vegetative (*Falcataria moluccana-Vigna cylindrica*) and terrace systems in soils of different slopes. Biodiversitas 20: xxxx.* Soil and water conservation techniques involving a combination of vegetative and mechanical systems will increase the benefits from both consevation aspect as well as economic aspect. This study was aimed at analyzing the silvicultural, hydro-orological and economic aspects of a combination of vegetative (*Falcataria moluccana - Vigna cylindrica*) and terrace system in soils of different slopes (a steep and a very steep slope gradient). The silvicultural parameters examined in this study were the ground coverage of *V. cylindrica* growth and survival rate, stem diameter and height of *F. moluccana* trees. The hydro-orological parameters included erosion rate, erosion hazard index, erosion hazard class and erosion hazard level. The economic parameters included total cost, total revenue and profit. The result showed that the survival rate , diameter increment and height increment of *F. moluccana,* and ground coverage of *V. cylindrica* in the land with the steep slope (>25-45%) was 90%, 2.02 cm year^{-1}, 1.54 m year^{-1}, and 80-90%, respectively. The erosion rate, erosion hazard index, erosion hazard class, and erosion hazard level in this steep slope was 0.38 ton ha year^{-1}, 0.03 (low), I (very low), and very low, respectively. In the steeper ground (>45%), the survival rate of *F. moluccana* reached 90%, the *V. cylindrica* coverage was 70-79% and the diameter and height increment of *F. moluccana* was 1.63 cm year^{-1} and 1.19 m year^{-1}, respectively. The erosion rate was 1.81 ton ha^{-1} year^{-1}, erosion hazard index of 0.13 (low), erosion hazard class was I (very low), and erosion hazard level was low in the very steep slope land. The profit from *V. cylindrica* was Rp 3,865,000.00 ha^{-1} cropping season^{-1} and Rp 665,000.00 ha^{-1} cropping season^{-1} in steep slope and very steep slope, respectively. The application of the proposed combination of vegetative and terrace system could reduce surface run off and erosion rate in the long term, in addition to providing short term economic benefits.

Keywords: Economic, hydro-orological, silvicultural, slope, terrace

INTRODUCTION

The over exploitation of natural resources which has exceeded the carrying capacity, coupled with population pressure on land resourcess, will lead to an increase in degraded land area. In Indonesia, 78 million ha area of land has been catagorized as degraded land, of which, 48 million ha is slightly degraded area, 23 million ha is moderately degraded area and 7 million ha is highly degraded area (ADB 2016). The implementation of soil and water conservation and other land rehabilitation at in situ and catchment level is the highest priority to manage highly degraded environments and pressured lands (Nyssen et al. 2008). The application of vegetative barriers and mechanical technique, such as bunds or trenches or both, on the appropriately spaced contours may increase potential conservation role (Dass et al. 2011).

Soil reaction primarily influences plant growth indirectly through its effects on the solubility of ions and the activity of microorganiss (Harris 1992). The easily observable properties of soil, such as texture, structure, colour, depth and stoniness, can be used to infer agreat deal about how a particular soil influences plant growth (Fisher and Binkley 2000). It is the ability of the soil to supply nutrient elements in the amounts, forms, and proportions required for maximum plant growth (Hazra and Som 2006). There are association between species and soil characteristics under homogenous parent rock and elevational range (Nizam et al. 2006) as well as correlation among topography, soil nutrient and plants (Potts et al. 2002). In addition, several soil properties showed positive and negarive correlation to plant parameters (Kumar et al. 2010; Toledo et al. 2011).

The mixed cropping of sengon *(Falcataria moluccana)* and peanut (*Arachis hypogaea*) as well as jabon *(Anthocephalus cadamba)* and soybeans (*Glycine max*) could be implemented in different soil slopes for rehabilitating and soil conservation in sloping lands, based on the growth and hydro-orological parameters (Karyati et al. 2018; Sarminah et al. 2018). These two agroforestry systems of *F. moluccana - A. hypogaea* and *A. cadamba - G. max* are feasible and applicable to rehabilitate and conserve the critical lands. Although planting of *G. max* was not profitable in some critical lands, the agroforestry system of *A.cadamba* and *G. max* still had many benefits from the aspect of ecology and conservation for long terms (Karmini et al. 2017).

Yard long bean (*Vigna sesquipedalis* L. Fruw) is one of the most popular vegetables in many countries of Southeast Asia, but this species has relatively low yield productivity (Nooprom and Santipracha 2015). The production, harvested area, and productivity of *Vigna cylindrica* (long beans) in Indonesia in 2017 was 381,185 ton; 56,111 hectare, and 6.79 ton hectare^{-1}, respectively (Ministry of Agriculture Republic of Indonesia 2018). In East Kalimantan, the production of *V. cylindrica* in 2017 was 71,456 quintal, while harvested area and productivity was 1,361 hectare and 52.50 quintal hectare^{-1}. The productivity of *V. cylindrica* in Samarinda in 2017 was 26.86 quintal hectare^{-1}, total production was 3,089 quintal and the harvested area of 115 hectare (Ministry of Agriculture Republic of Indonesia 2018; Statistics of East Kalimantan Province 2018).

The total land area of Samarinda City of East Kalimantan Province is 71.800,00 ha, out of which land area with less than 2% slope is 27.39%, 2-15% slope is 25.47%, 15-25% slope is14.81%, 25-40% slope is 15.67%, and more than 40% slope is 13.02% (Statistics of East Kalimantan Province 2018). A combination of vegetative and terrace techniques of soil and water conservation may be the appropriate choice to rehabilitate sloping lands based on silvicultural, hydro-orological and economic aspects. The plantations of forestry plants is hoped to provide silvicultural, conservation and economic values in a long term program. On the other hand, planting of agricultural plants is expected to provide short term economic benefits. The objectives of this study were to investigate silvicultural, hydro-orological and economic aspects of implementation of a combination of vegetative (*F. moluccana*-*V. cylindrica*) and terrace systems in different soil slopes, ranging from steep to very steep slope gradients.

MATERIALS AND METHODS

Study area

This study was conducted in Educational Forest of Forestry Faculty of Mulawarman University, Lempake District, Samarinda City, East Kalimantan Province. The study duration was six months, from January to June 2018. The experimental forest covered a total area of 300 ha and was located at 0°25'10"–0°25'24" South latitude and 117°14'00"–117°14'14" East longitude, in between kilometers 10 and 13 of the Samarinda-Bontang Highway. Administratively, this experimental forest is situated in Tanah Merah Village, North Samarinda District, Samarinda City, East Kalimantan Province.

The study area received 211.5 mm monthly average rainfall, average air temperature is 27.4°C, and relative humidity was 82.2%. The average daily temperature and relative humidity inside the forest ranged from 23.7°C to -30.9°C and 81.4% t0 99.3%, respectively. The average daily temperature and relative humidity outside the forest was 25.9°C-28.8°C and 76.0%-90.0%, respectively. The daily average light intensity ranged from 1.08 µmol to 18.41 µmol (Karyati and Ardianto 2016). The climate of Samarinda City was classified as type A climate (a quotient (Q) of 4.8 per cent) based on Schmidt and Ferguson (1951) system which is characterized by highly humidity with a tropical rainforest vegetation..

Procedures

Experimental procedures

Experiments were conducted in two 10 m x 10 m experimental plots which were located in areas with two different slope classes inside the experimental forest. One of these two experimental plots had a steep slope (>25-45%) and other had a very steep slope (>45%).

2 m wide terraces were made in each experiental plot. Terrace was completed by ditches sized 25 cm wide and 10 cm depth. Sengon (*F. moluccana*) and long beans (*V. cylindrica*) were planted on both plots. *F. moluccana* trees were planted with a spacing of 3 m × 3 m. *V. cylindrica*, as the intercrop legume, was grown in between the sengon trees. Two erosion measurement plots of 10 m × 3 m size were placed in each of the two experimental plots. The growth paremeters were measured once in every month, for four months period. Plants were maintained by regular watering, weeding, fertilizer application, and pest and disease control. For economic evaluation, only the long beans were harvested, but not the sengon trees. The measurement of hydro-orological parameters were conducted during 27 times rain events.

Analysis of soil properties

The analysis of soil physicochemical properties, such as pH, C organic, total N, P, K, and soil texture, were conducted in Laboratory of Soil Science, Tropical Forest Research Center, Mulawarman University. Soil pH was determined in distilled water and 1 N KCl in a soil to solution ratio of 1:2.5 by the glass electrode method. The C organik and total nitrogen (total N) were analyzed using Walkley and Black method (1934) and Kjeldahl method (1883), respectively. Soil P and K were analyzed using Bray 1 method (1954).

Data analysis

Silvicultural parameters

The observation and measurement of plant growth was conducted at the end of every month for four months. The observation was carried out on both *F. moluccana* and *V. cylindrica* plants. The parameters studied for *F. moluccana* were plant survival rate, tree height, and stem diameter. For *V. cylindrica*, ground coverage and yield was recorded. The plant health was measured for both *F. moluccana* and *V. cylindrica*. A healthy plant was characterized as a plant with a normal height, fresh green leaves, normal stem, and no disease/pests and weed (Ministry of Forestry Republic of Indonesia 2009).

Hydro-orological parameter

The hydro-orological parameters measured in this study were surface runoff, potential soil erosion rate, erosion hazard index, erosion hazard class, and erosion hazard level (Hammer 1981). The erosion hazard index categories and erosion hazard level classification are shown in Table 1 and Table 2, respectively. The erosion hazard index is determined as potential erosion rate (ton ha^{-1} year^{-1}) divided by tolerable erosion rate (ton ha^{-1} year^{-1}) (Hammer 1981).

Economic analysis

In this study, the analyzed economic aspects were cost, revenue and profit from long beans as intercropping in sengon (long beans) agroforestry systems. Cost is calculated from price and quantity of inputs, revenue is the price of produced yield, and profit is revenue minus cost (Slavin 2009).

RESULTS AND DISCUSSION

Silvicultural aspects

The recorded plant growth parameters of *F. moluccana* and *V. cylindrica* for the two different slope classes are summarized in Table 3. The growth of *F. moluccana* and *V. cylindrica* combination were "moderate" to "very good" in the steep slope and very steep slope. The survival rate of *F. moluccana* in both slope classes wwas "very good" (90%). The ground coverage of *V. cylindrica* in steep slope was better (80-89%) than in very steep slope (70-79%). Meanwhile, the yield of *V. cylindrica* was also higher (2,500 kg ha^{-1}) in steep slope when compared to the yield in very steep slope (2,100 kg ha^{-1}).

The average of *V. cylindrica* yield in this study was almost similar to the average of Samarinda's yield, but lower than East Kalimantan and Indonesia's yield (Ministry of Agriculture Republic of Indonesia 2018; Statistics of East Kalimantan Province 2018). However, *V. cylindrica*'s yield obtained in this study was lower than reported by Wahyu et al. (2018). Wahyu et al. (2018) reported that the productivity of *V. cylindrica* in Samboja Subdistrict, Kutai Kartanegara District, East Kalimanatn Province was 7,010 kg ha^{-1} and 13,640 kg ha^{-1} from monoculture and agroforestry systems, respectively.

The monthly diameter and height increments of *F. moluccana* trees, measured for four months, are provided in Tables 4 and 5. The stem diameter and height increment of *F. moluccana* trees is faster in the slightly steep slope than in the highly steeper slope. The average stem diameter and height increments of *F. moluccana* were 2.02 cm year^{-1} and 1.54 m year^{-1} in the steep slope, and 1.63 cm year^{-1} and 1.19 m year^{-1}, in very steep slope.

The average diameter increment of *F. moluccana* in *F. moluccana* and *V. cylindrica* agroforestry system (on steep and very steep slopes) was lower than those in *F. moluccana* and *Arachis hypogaea* agroforestry system (on slight steep and steep slopes) as reported by Sarminah et al. (2018). On the contrary, the average height increment of this combination was higher than those reported by Sarminah et al. (2018). Similarly, the diameter increment of *F. moluccana* in this study was also lower than those in agroforestry system, monoculture system, and intensive monoculture system (Swestiani and Purwaningsih 2013; Wahyudi and Panjaitan 2013). However, the average diameter increments of *F. moluccana* trees on the steep slope was higher than those planted in the conventional monoculture system (Wahyudi and Panjaitan 2013).

Hydro-orological aspects

The hydro-orological aspects were determined by surface runoff and eroded soil mass. Table 6 presents data regarding rainfall, eroded soil mass, and surface runoff volume in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system in the two different slope classes. The result showed that the higher rainfall results in surface runoff and eroded soil mass. Several factors such as rainfall, slope, cover crop, and management practices have suspected influence on soil erosion in the study sites. The length and gradient of slope influences soil erosion. In the steeper slope lands, the rainfall tend to transport the soil particles into lower area faster. It will increase surface runoff and eroded soil mass as well erosion rate. The increasing slope and rain intensity have increased the runoff rate from 20% to 90% (Chaplot and LeBissonnais 2000).

Table 1. Erosion hazard index categories

Erosion hazard index	Category
< 1.00	Low
1,01-4,00	Moderate
4,01-10,00	High
> 10,01	Very high

Source: Hammer (1981)

Table 2. Erosion hazard level classification

Soil column (cm)	Erosion class				
	I	II	III	IV	V
	Erosion rate (ton ha^{-1} year^{-1})				
	<15	15-<60	60-<180	180-480	>480
Deep (>90)	Very low 0	Low I	Moderate II	Heavy III	Very heavy IV
Intermediate (60-90)	Low I	Moderate II	Heavy III	Very high IV	Very heavy IV
Shallow (30-<60)	Moderate II	Heavy III	Very heavy IV	Very heavy IV	Very heavy IV
Very shallow (<30)	Heavy III	Very heavy IV	Very heavy IV	Very heavy IV	Very heavy IV

Source: Regulation of Directorate General of Watershed Management and Social Forestry, Ministry of Forestry Republic of Indonesia (2013). Note: 0=Very low; I=Low; II=Moderate; III=Heavy; IV=Very heavy

Table 3. The growth parameters of *F. moluccana* and *V. cylindrica* in the two different slope classes

Plant species	Steep slope (>25-45%)				Very steep slope (>45%)			
	Healthy plants (%)	Survival rate (%)	Ground coverage (%)	Yield (kg ha^{-1})	Healthy plants (%)	Survival rate (%)	Ground coverage (%)	Yield (kg ha^{-1})
F. moluccana	90 (Very good)	90 (Very good)	-	-	90 (Very good)	90 (Very good)	-	-
V. cylindrica	80-89 (Good)	-	80-89 (Good)	2,500	70-79 (Moderate)	-	70-79 (Moderate)	2,100

Table 4. *Falcataria moluccana* stem diameter increments (mm) in the two different slopes classes

Tree number	Steep slope (>25-45%)					Very steep slope (>45%)				
	D_0	d_1	d_2	d_3	d_4	D_0	d_1	d_2	d_3	d_4
1	12.10	12.85	14.15	16.15	18.68	14.40	15.00	16.05	18.25	21.10
2	9.25	10.00	11.25	12.80	15.00	6.20	6.95	7.90	9.25	11.00
3	8.20	8.90	10.10	11.65	13.85	9.10	9.70	11.00	12.95	15.50
4	5.10	7.80	9.05	10.60	12.50	9.70	10.20	11.25	12.75	15.10
5	12.70	13.65	14.95	16.90	19.25	11.10	11.65	12.90	14.85	17.35
6	8.60	9.55	11.00	12.70	14.75	6.75	7.35	8.30	9.60	11.25
7	5.30	8.00	9.20	10.90	13.00	6.60	7.30	8.40	9.85	11.70
8	7.40	8.15	9.40	11.05	13.00	6.40	7.00	7.95	9.40	11.15
9	10.30	10.90	12.05	13.55	15.50	8.40	9.00	9.95	11.30	13.00
10	10.10	10.80	12.20	13.90	16.10	10.40	11.10	12.15	14.05	16.45
11	5.70	8.50	9.75	11.40	13.55	8.20	8.85	9.80	11.15	12.90
12	10.30	11.20	12.45	14.20	16.60	9.10	10.00	11.50	13.30	15.65
13	11.40	12.10	13.40	15.55	18.20	7.10	7.75	8.80	10.30	12.05
14	6.30	9.10	10.20	12.05	14.15	10.35	11.00	12.20	13.70	15.65
15	10.80	11.50	12.90	14.95	17.55	7.25	8.00	9.10	10.50	12.20
16	4.15	8.75	9.75	11.55	13.65	14.40	15.15	16.50	18.29	20.19
Mean	8.61	10.11	11.36	13.12	15.33	9.09	9.75	10.86	12.47	14.52
SD	2.69	1.81	1.86	1.99	2.17	2.58	2.58	2.66	2.88	3.16
Annual diameter increment	20.18 mm year^{-1} = 2.02 cm year^{-1}					Annual diameter increment: 16.27 mm year^{-1}= 1.63 cm year^{-1}				

Note: D_0 = initial stem diameter (diameter measurement at the beginning of experiment); d_1, d_2, d_3, d_4 = diameter at the end of the first, second, third, and fourth month after planting; SD=Standard Deviation

Table 5. *F. moluccana* height increments (cm) in the two different slopes

Tree number	Steep slope (>25-45%)					Very steep slope (>45%)				
	H_0	h_1	h_2	h_3	h_4	H_0	h_1	h_2	h_3	h_4
1	153	177	189	205	213	176	197	205	210	220
2	144	157	182	194	206	160	173	182	201	205
3	102	106	111	117	125	143	153	157	164	174
4	176	188	196	202	212	124	136	148	155	166
5	165	183	204	212	227	146	163	166	171	176
6	157	172	194	204	212	123	138	145	158	161
7	167	179	187	200	209	145	157	167	176	188
8	146	167	183	192	204	151	165	178	182	194
9	182	205	219	231	242	146	162	166	175	181
10	184	197	208	219	231	164	177	186	199	206
11	116	131	143	159	177	173	185	189	194	208
12	119	136	148	163	176	152	163	169	175	184
13	159	173	183	195	208	119	134	142	154	162
14	168	184	194	212	220	169	186	190	202	214
15	169	185	198	211	221	134	149	158	167	178
16	137	150	163	172	181	101	113	126	136	144
Mean	153	168	181	193	204	145	159	167	176	185
SD	24,10	26,21	27,59	28,10	28,03	21,03	22,03	20,79	20,69	21,48
Annual height increment	153.75 cm year^{-1} =1.54 m year^{-1}					Annual height increment: 119.1 cm year^{-1} =1.19 m year^{-1}				

Note: H_0 = initial tree height (height measurement at the beginning of experiment); h_1, h_2, h_3, h_4 = height at the end of the first, second, third, and fourth month after planting; SD=Standard Deviation.

Table 6. Rainfall, surface runoff volume, and eroded soil mass in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system in the two different slope classes

Rain event	Rainfall (mm)	Surface runoff (L)		Eroded soil mass (g/30 m²)	
		Steep slope (>25-45%)	Very steep slope (>45%)	Steep slope (>25-45%)	Very steep slope (>45%)
1	74	46.74	43.40	128.76	111.59
2	37	12.21	46.74	39.93	631.4
3	14	7.87	46.74	13.51	149.74
4	20	7.87	46.74	9.22	164.05
5	41	46.74	46.26	119.22	348.13
6	21	14.95	47.21	47.72	214.6
7	36	46.74	46.74	62.95	147.84
8	22	15.74	46.74	32.75	115.41
9	7	4.72	7.79	4.96	25.43
10	15	6.30	46.74	11.06	97.29
11	13	6.23	15.74	6.49	105.87
12	22	23.37	47.21	14.31	75.35
13	31	46.74	47.21	32.43	61.04
14	49	11.8	46.74	18.12	96.33
15	10	6.3	47.21	2.8	57.23
16	10	6.3	17.92	2.03	15.36
17	17	7.87	46.74	2.07	22.89
18	5	8.66	30.69	0.7	24.18
19	9	4.72	31.48	0.38	8.9
20	14	7.87	46.74	0.16	15.26
21	28	7.87	46.74	2.07	34.34
22	41	14.16	47.21	1.14	14.31
23	42	37.77	47.21	3.05	35.29
24	21	11.02	47.21	1.11	25.75
25	27	11.80	46.74	0.72	16.21
26	10	7.87	47.21	0.16	11.45
27	45	15.74	47.21	0.32	8.58
Total	681	445.92	1132.26	558.13	2633.81
Average	25	16.52	41.94	20.67	97.55

Table 7. The hydro-orological parameters in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system in the two different slope classes

Slope gradient	Surface runoff rate (m^3 ha^{-1} $year^{-1}$)	Potential erosion rate (ton ha^{-1} $year^{-1}$)	Tolerable erosion rate (ton $ha^{-1}$$year^{-1}$)	Erosion hazard index	Erosion hazard class	Erosion hazard level
>25-45%	305.77	0.38	25[1)]	0.03 (Low)	I (Very low)	Very low
>45%	776.41	1.81	25[1)]	0.13 (Low)	I (Very low)	Vey low

[1)]Soil depth in the study plot was >100 cm and the tolerable erosion rate for hills or slope lands was 25 ton $ha^{-1}$$year^{-1}$ (Rahim 1995)

Table 8. Comparison of soil erosion reported in the current study with earlier reports for other agroforestry plantation systems

Planting system	Erosion (ton $ha^{-1}$$year^{-1}$)	Location	Researcher (year)
Soil and water conservation technique and application of agroforestry system	190.08	Ngadipiro Village. Nguntoronadi Sub-district. Wonogiri District. Central Java. Indonesia	Sumarno et al. (2011)
Agroforestry system of *A. cadamba* and *Glycine max*		East Kalimantan. Indonesia	Karyati et al. (2018)
Slope of >15-25%	32.13		
Slope of >25-45%	52.51		
Agroforestry system of *F. moluccana* and *A. hypogaea*		East Kalimantan. Indonesia	Sarminah et al. (2018)
Slope of >15-25%	20.05		
Slope of >25-45%	45.50		
Agroforestry system of *F. moluccana* and *V. cylindrica*		East Kalimantan. Indonesia	Current study
Slope of >25-45%	0.38		
Slope of >45%	1.81		

Table 9. Economic analysis of growing *V. cylindrica* as intercrop in vegetative (*F. moluccana - V. cylindrica*) and terrace combination system in the two different slope classes

No.	Item/activity	Quantity	Unit	Price (Rp)	Total (Rp. $ha^{-1}cs^{-1}$)
Production cost					
Material cost					
1	*F. moluccana* seedlings	1,350.00	units ha^{-1}	3,000.00	4,050,000.00
2	*V. cylindrica* seeds	350.00	units ha^{-1} cs^{-1}	15,000.00	5,250,000.00
3	NPK fertilizer	100.00	kg ha^{-1} cs^{-1}	15,000.00	1,500,000.00
4	Pesticides	25.00	kg ha^{-1} cs^{-1}	30,000.00	750,000.00
5	Plastic strings	1.00	units ha^{-1} cs^{-1}	30,000.00	30,000.00
6	Gunny sacks	20.00	units ha^{-1} cs^{-1}	2,000.00	40,000.00
7	Fertilizer	50.00	units ha^{-1} cs^{-1}	25,000.00	1,250,000.00
	Sub total				12,870,000.00
Depreciation cost					
8	Hoe	2.00	units ha^{-1}	125,000.00	20,833.33
9	Chopper	2.00	units ha^{-1}	100,000.00	16,666.67
10	Sickle	2.00	units ha^{-1}	60,000.00	10,000.00
11	Sprayer	1.00	units ha^{-1}	350,000.00	17,500.00
	Sub total				65,000.00
Labor cost					
12	Land preparation	7.00	days ha^{-1} cs^{-1}	100,000.00	700,000.00
13	Planting	6.00	days ha^{-1} cs^{-1}	100,000.00	600,000.00
14	Fertilizing	4.00	days ha^{-1} cs^{-1}	100,000.00	400,000.00
15	Weeding	5.00	days ha^{-1} cs^{-1}	100,000.00	500,000.00
16	Pest and disease controlling	4.00	days ha^{-1} cs^{-1}	100,000.00	400,000.00
17	Harvesting	6.00	days ha^{-1} cs^{-1}	100,000.00	600,000.00
	Sub total				3,200,000.00
Total cost					16,135,000.00
Total revenue from *V. cylindrica*					
	Steep slope plot (>25-45%)	2,500.00	kg ha^{-1}	8,000.00	20,000,000.00
	Very steep slope plot (>45%)	2,100.00	kg ha^{-1}	8,000.00	16,800,000.00
Profit		Steep slope plot (>25-45%)			3,865,000.00
		Very steep slope plot (>45%)			665,000.00

Note: cs = cropping season

The implementation of vegetative and terrace system was hoped to reduce the potential soil erosion. Generally, the best recommendation for soil and water conservation technology was to combine the vegetative and mechanical systems because such combinations are usually best for reducing soil erosion and decreasing conservation cost in long term as well as increasing short term economical benefits. The *F. moluccana* trees and *V. cylindrica* play a role as cover crop in the sloping lands that could avoid destructive effect of rainfall. In addition, the application of terrace system could reduce surface runoff and increase water infiltration into the deeper soils. Terrace agriculture could be adapted as a land-management practice and innovation in terms of the region and local conditions (Bocco and Napoletano 2017).

The erosion rate is also affected by soil properties, especially soil texture. The soil texture in the study site is silty loam that usually support the greatest diversity of plant life. The silt tends to be loaded with the soluble nutrients required by plants. The silt soil also has high content of organic matter. The soil in the study plots was categorized as acidic soil, indicated by the pH value of lower than 5 and the low content of organic C, total N, P, and K. Tanaka (1999) stated the soil acidity could be a good indicator for the composition of exchangeable cations and it provided the capacity of the deeper surface to supply exchangeable bases to plant. It was regardless that the acidic nature of the soils might be due to the loss of exchangeable bases through uptake by plant and leaching under tropical environment (Hamzah et al. 2009)

The evaluation of erosion hazard index, erosion hazard class, and erosion hazard level could be used as an indicator to determine the erosion status in the area. The hydro-orological parameters recorded in this study are shown in Table 7. The tolerable erosion rate for sloping lands is 25 ton $ha^{-1}year^{-1}$ at a soil depth of more than 100 cm (Rahim 1995). The erosion rate of both steep slope and very steep slope plots were less than 15 ton $ha^{-1}year^{-1}$ while the soil depth in the plot was more than 90 cm. The potential erosion rates in steep slope and very steep slope in studied plots were 0.38 ton $ha^{-1}year^{-1}$ and 1.31 ton $ha^{-1}year^{-1}$, respectively. The erosion hazard index was 0.03 (low) and 0.13 (low) for steep slope and very steep slope plots, respectively. The erosion hazard classes (class I) and erosion hazard level in both studied slopes belong to "very low" category.

The soil erosion rates recorded in the current study was lower than the values reported for some other agroforestry systems (Karyati et al. 2018; Sarminah et al. 2018; Sumarno et al. 2011) as presented in Table 8. This result implied that the combination of vegetative (*F. moluccana* and *V. cylindrica*) and terrace system could be effectively implemented in different sloping lands.

Economic aspects

The implementation of vegetative (*F. moluccana-V. cylindrica*) and terrace system in different slope classes involves cost expenditure to buy planting and other materials, depreciation on equipments and wages of labor. On the other hand, implementation of this method gives revenue and profit, especially from *V. cylindrica* yield. Table 9 shows economic analysis of *V. cylindrica* as intercrop in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system in the two different slope classes. The material cost involved were for buying *F. moluccana* seedlings, *V. cylindrica* seeds, NPK fertilizer, pesticides, plastic strings, gunny sacks, and fertilizersto increase soil fertility. The profit of *F. moluccana-V. cylindrica* plantation in steep slope was Rp 3,865,000.00 ha^{-1} cs^{-1} and in very steep slope was Rp 665,000.00 ha^{-1} cs^{-1}. This profit was from selling the yield from *V. cylindrica*.

The profit from *V. cylindrica* yield in steep slope was higher than *A. hypogaea* yield on agroforestry system of *F. moluccana-A. hypogaea* as reported by Karmini et al. (2017). The total cost, total revenue and profit related to *F. moluccana* and *A. hypogaea* agroforestry system was Rp 10,985,000 ha^{-1} cs^{-1}, Rp 14,000,000 ha^{-1} cs^{-1} and Rp 3,015,000 ha^{-1} cs^{-1}. However, growing *V. cylindrica* as intercrop in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system in different slope lands is highly benefitial when compared to growing *G. max* in *A. cadamba - G. max* agroforestry system. Karmini et al. (2017) reported that growing *G. max* in *A. cadamba - G. max* agroforestry system involved total cost of Rp 11,019,000.00 ha^{-1} cs^{-1}, total revenue was Rp 3,500,000 ha^{-1} cs^{-1}, and the profit was Rp (-)7,519,000.00 ha^{-1} cs^{-1}. The planting arbor trees and shrubs densely on the terrace riser slope could suppress gravity erosion, allow intensive cultivation, add economic benefits and extend development of the landscape efficiently (Cao et al. 2007).

The implementation of a combination of vegetative and terrace system for soil and water conservation could be applied in the different slope lands. This practice will be benefitial based on silvicultural, hydro-orological, and economic aspects. The short term economic benefit is provided by agricultural yield from the crop plant. In long term, this practice is benefitial in terms of soil and water conservation and environment aspects. The information of this study on silvicultural, hydro-orological and economic aspects could be used for recommending alternative agroforestry systems in small scale, and soil conservation programs in a wide scale for all stakeholders including farmers, foresters, private parties and the governmental agencies concerned with land management and soil conservation activities.

ACKNOWLEDGEMENTS

The authors wish to express their thanks to Ministry of Research, Technology and Higher Education, Republic of Indonesia for supporting *Hibah Penelitian Strategis Nasional Institusi* Contract Number: 140/UN17.41/KL/2018.

REFERENCES

ADB. 2016. Indonesia Country Water Assessment. Manila. (PATA 8432-INO). ADB, Mandaluyong City, Philippines.

Bocco G, Napoletano BM. 2017. The prospects of terrace agriculture as an adaptation to climate change in Latin America. Geography Compass. 2017;11:e12330. https://doi.org/10.1111/gec3.12330

Bray RH. 1954. A nutrient mobility concept of soil-plant relationships. Soil Sci 78(1): 9–22.

Cao S, Chen L, Feng Q, Liu Z. 2007. Soft-riser bench terrace design for the hilly loess region of Shaanxi Province, China. Landscape and Urban Planning 80: 184–191.

Chaplot V, LeBissonnais Y. 2000. Field measurements of interrill erosion under different slopes and plot sizes. Earth Surf Proces Landf 25: 145-153.

Dass A, Sudhishri S, Lenka NK, Patnaik US. 2011. Runoff capture through vegetative barriers and planting methodologies to reduce erosion, and improve soil moisture, fertility and crop productivity in southern Orissa, India. Nutr Cycl Agroecosyst 89:45–57.

Fisher RF, Binkley D. 2000. Ecology and Management of Forest Soils, 3rd Ed. John Wiley & Sons, Inc, USA.

Hammer WI. 1981. Second soil conservation consultant report. AGOF/INS/78/006. Tech. Note No. 10. Centre for Soil Research, Bogor.

Hamzah MZ, Arifin A, Zaidey AK, Azirim AN, Zahari I, Hazandy AH. 2009. Characterizing soil nutrient status and growth performance of planted dipterocarp and non-dipterocarp species on degraded forest land in Peninsular Malaysia. Journal of Applied Sciences 9 (24): 4215-4223.

Harris RW. 1992. Arboriculture: Integrated Management of Landscape Trees, Shrubs, and Vines. Prentice Hall Career & Technology. New Jersey.

Hazra P, Som MG. 2006. Vegetable Science. Kalyani Publishers. New Delhi.

Karmini, Sarminah S, Karyati. 2017. Economic analysis of groundnut (*Arachis hypogaea*) and soybean (*Glycine max*) as intercropping plants in two agroforestry systems. Biodiversitas 18 (2): 483-493.

Karyati, Ardianto S. 2016. Dinamika suhu tanah pada kedalaman berbeda di Hutan Pendidikan Fakultas Kehutanan Universitas Mulawarman. Jurnal Riset Kaltim 4 (1): 1-12. [Indonesian]

Karyati, Sarminah S, Karmini, Simangunsong G, Tamba J. 2018. The mixed cropping of *Anthocephalus cadamba* and *Glycine max* for rehabilitating sloping lands. Biodiversitas 19(6): 2088-2095.

Kjeldahl J. 1883. New method for the determination of nitrogen. Chem News 48(1240): 101–102.

Kumar JIN, Kumar RN, Bhoi RK, Sajish PR.2010. Tree species diversity and soil nutrient status in three sites of tropical dry deciduous forest of western India. Tropical Ecology 51(2): 273-279.

Ministry of Agriculture Republic of Indonesia. 2018. Agricultural Statistics 2018. Ministry of Agriculture Republic of Indonesia, Jakarta. [Indonesia]

Nizam MS, Norziana J, Sahibin AR, Latiff A. 2006. Edaphic relationships among tree species in the National Park at Merapoh, Pahang, Malaysia. Jurnal Biosains 17(2): 37-53.

Nooprom K, Santipracha Q. 2015. Effect of varieties on growth and yield of yard long bean under Songkhla Conditions, Southern Thailand. Modern Applied Science 9(13): 247-251.

Nyssen J, Poesen J, Deckers J. 2008. Land degradation and soil and water conservation in tropical highlands. Soil Tillage Res. doi:10.1016/j.still.2008.08.002

Potts MD, Ashton PS, Kaufman LS, Plotkin JB. 2002. Habitat patterns in tropical rain forest: A comparison of 105 plots in northwest Borneo. Ecology 83(10): 2782-2797.

Rahim SE. 1995. Erosi Tanah dan Pemodelan Pendugaannya dalam Dinamika Lingkungan Hidup Sumatera Selatan. PPLH Lembaga Penelitian Universitas Sriwijaya. [Indonesian]

Regulation of Ministry of Forestry Republic of Indonesia, Ministry of Forestry Republic of Indonesia Number: P.60/Menhut-II/2009. [Indonesian]

Regulation of Directorate General of Watershed Management and Social Forestry, Ministry of Forestry Republic of Indonesia Number: P.4/V-SET/2013. [Indonesian]

Sarminah S, Karyati, Karmini, Simbolon J, Tambunan E. 2018. Rehabilitation and soil conservation of degraded land using sengon (*Falcataria moluccana*) and peanut (*Arachis hypogaea*) agroforestry system. Biodiversitas 19 (1): 222-228.

Schmidt FH, Ferguson JHA. 1951. Rainfall types based on wet and dry period ratios for Indonesia and western New Guinea. Kementerian Perhubungan Djawatan Meteorologi dan Geofisik, Verhandelingen No. 42.

Slavin SL. 2009. Economics. McGraw-Hill Irwin, New York.

Sumarno, Winarno J, Prastomo I. 2011. Kajian pengelolaan lahan berdasarkan tingkat bahaya erosi dan pola konservasi tanah dan air di Desa Ngadipiro Kecamatan Nguntoronadi, Kabupaten Wonogiri. Sains Tanah-Jurnal Ilmu Tanah dan Agroklimatologi 8 (1): 13-22. [Indonesian]

Swestiani D, Purwaningsih S. 2013. Produksi kacang tanah (*Arachis hypogaea* L.) pada agroforestri berbasis kayu sengon dan manglid. Jurnal Penelitian Agroforestri 1(2): 71-82. [Indonesian]

Statistics of East Kalimantan Province. 2018. Kalimantan Timur Province in Figure 2018. BPS Statistics of East Kalimantan Province, Samarinda. [Indonesian]

Tanaka S. 1999. Soil ecological study on shifting cultivation in the mountains area in Northern Thailand. Faculty of Agriculture, Kochi University. Nankoku, Japan.

Toledo M, Poorter L, Peña-Claros M, Alarcón A, Balcázar J, Leaño C, Licona JC, Llanque O, Vroomans V, Zuidema P, Bongers F. 2011. Climate is a stronger driver of tree and forest growth rates than soil and disturbance. Journal of Ecology 99: 254-264.

Wahyu I, Pranoto H, Supriyanto B. 2018. Kajian produktivitas tanaman semusim pada sistem agroforestri di Kecamatan Samboja Kabupaten Kutai Kartanegara. Agroekoteknologi Tropika Lembab 1(1): 24-33. [Indonesian]

Wahyudi, Panjaitan S. 2013. Perbandingan sistem agroforestri, monokultur intensif, dan monokultur konvensional dalam pembangunan hutan tanaman sengon. Prosiding Seminar Nasional Agroforestri 165-171. [Indonesian]

Walkley A, Black IA. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci 37: 29-38.

BIODIVERSITAS
Volume 20, Number 8, August 2019
Pages: xxxx

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d2008xx

Silvicultural, hydro-orological and economic aspects of a combination of vegetative (*Falcataria moluccana-Vigna cylindrica*) and terrace systems in soils of different slopes

KARYATI[1,♥], SRI SARMINAH[1], KARMINI[2,♥♥], RUJEHAN[1], VEBI FITRIANA EKO LESTARI[1], WENDY SATRIA PANORAMA[1]

[1]Faculty of Forestry, Mulawarman University, Gunung Kelua Campus, Jalan Ki Hajar Dewantara, Samarinda, East Kalimantan, Indonesia 75119 Phone. +62-541-35089 Fax. +62-541-732146, ♥email: karyati@fahutan.unmul.ac.id, karyati.hanapi@yahoo.com

[2]Faculty of Agriculture, Mulawarman University, Gunung Kelua Campus, Jalan Pasir Balengkong, Samarinda, East Kalimantan, Indonesia 75119, ♥♥email: karmini@faperta.unmul.ac.id, karmini.kasiman@yahoo.com

Manuscript received: 12 July 2019. Revision accepted: xxx July 2019.

Abstract. *Karyati, Sarminah S, Karmini, Rujehan, Lestari VFE, Panorama WS. 2019. Silvicultural, hydro-orological and economic aspects of a combination of vegetative (*Falcataria moluccana-Vigna cylindrica*) and terrace systems in soils of different slopes. Biodiversitas 20: xxxx.* Soil and water conservation techniques involving a combination of vegetative and mechanical systems will increase the benefits from both consevation aspect as well as economic aspect. This study was aimed at analyzing the silvicultural, hydro-orological and economic aspects of a combination of vegetative (*Falcataria moluccana - Vigna cylindrica*) and terrace system in soils of different slopes (a steep and a very steep slope gradient). The silvicultural parameters examined in this study were the ground coverage of *V. cylindrica* growth and survival rate, stem diameter and height of *F. moluccana* trees. The hydro-orological parameters included erosion rate, erosion hazard index, erosion hazard class and erosion hazard level. The economic parameters included total cost, total revenue and profit. The result showed that the survival rate , diameter increment and height increment of *F. moluccana,* and ground coverage of *V. cylindrica* in the land with the steep slope (>25-45%) was 90%, 2.02 cm year^{-1}, 1.54 m year^{-1}, and 80-90%, respectively. The erosion rate, erosion hazard index, erosion hazard class, and erosion hazard level in this steep slope was 0.38 ton ha year^{-1}, 0.03 (low), I (very low), and very low, respectively. In the steeper ground (>45%), the survival rate of *F. moluccana* reached 90%, the *V. cylindrica* coverage was 70-79% and the diameter and height increment of *F. moluccana* was 1.63 cm year^{-1} and 1.19 m year^{-1}, respectively. The erosion rate was 1.81 ton ha^{-1} year^{-1}, erosion hazard index of 0.13 (low), erosion hazard class was I (very low), and erosion hazard level was low in the very steep slope land. The profit from *V. cylindrica* was Rp 3,865,000.00 ha^{-1} cropping season^{-1} and Rp 665,000.00 ha^{-1} cropping season^{-1} in steep slope and very steep slope, respectively. The application of the proposed combination of vegetative and terrace system could reduce surface run off and erosion rate in the long term, in addition to providing short term economic benefits.

Keywords: Economic, hydro-orological, silvicultural, slope, terrace

INTRODUCTION

The over exploitation of natural resources which has exceeded the carrying capacity, coupled with population pressure on land resourcess, will lead to an increase in degraded land area. In Indonesia, 78 million ha area of land has been catagorized as degraded land, of which, 48 million ha is slightly degraded area, 23 million ha is moderately degraded area and 7 million ha is highly degraded area (ADB 2016). The degraded areas are caused by biophysical, social, economical and cultural factors (Matatula 2009). One way to increase the quality of degraded land is by using soil conditioners, combined with soil and water conservation techniques, organic matter management and appropriate fertilization based on soil analysis and plant requirement (Tala'ohu and Al-Jabri 2008). The application of cultivation techniques in the marginal and sloping lands has to be combined with the integrated environmental factors (Budiastuti 2013). The policy concept that was found to reduce erosion rate in watershed and sedimentation in reservoir is terrace and crop rotation system (Mardaeni et al. 2014). Edison et al. (2012) recommended vegetative land conservation technology to conserve cultivation land (*tegalan*), perennial plants in upstream area of *tegalan* and plantations in downstream area.

The mixed cropping of sengon *(Falcataria moluccana)* and peanut (*Arachis hypogaea*) as well as jabon *(Anthocephalus cadamba)* and soybeans (*Glycine max*) could be implemented in different soil slopes for rehabilitating and soil conservation in sloping lands, based on the growth and hydro-orological parameters (Karyati et al. 2018; Sarminah et al. 2018). These two agroforestry systems of *F. moluccana - A. hypogaea* and *A. cadamba - G. max* are feasible and applicable to rehabilitate and conserve the critical lands. Although planting of *G. max* was not profitable in some critical lands, the agroforestry system of *A.cadamba* and *G. max* still had many benefits from the aspect of ecology and conservation for long terms (Karmini et al. 2017). The production, harvested area, and productivity of *Vigna cylindrica* (long beans) in Indonesia in 2017 was 381,185 ton; 56,111 hectare, and 6.79 ton hectare^{-1}, respectively (Ministry of Agriculture Republic of Indonesia 2018; Statistics of Indonesia 2018). In East Kalimantan, the production of *V. cylindrica* in 2017 was 71,456 quintal, while harvested area and productivity was 1,361 hectare and 52.50 quintal hectare^{-1}. The productivity of *V. cylindrica* in Samarinda in 2017 was 26.86 quintal hectare^{-1}, total production was 3,089 quintal and the harvested area of 115 hectare (Ministry of Agriculture Republic of Indonesia 2018; Statistics of East Kalimantan Province 2018).

The total land area of Samarinda City of East Kalimantan Province is 71.800,00 ha, out of which land area with less than 2% slope is 27.39%, 2-15% slope is 25.47%, 15-25% slope is14.81%, 25-40% slope is 15.67%, and more than 40% slope is 13.02% (Statistics of East Kalimantan Province 2018). A combination of vegetative and terrace techniques of soil and water conservation may be the appropriate choice to rehabilitate sloping lands based on silvicultural, hydro-orological and economic aspects. The plantations of forestry plants is hoped to provide silvicultural, conservation and economic values in a long term program. On the other hand, planting of agricultural plants is expected to provide short term economic benefits. The objectives of this study were to investigate silvicultural, hydro-orological and economic aspects of implementation of a combination of vegetative (*F. moluccana-V. cylindrica*) and terrace systems in different soil slopes, ranging from steep to very steep slope gradients.

MATERIALS AND METHODS

Study area

This study was conducted in Educational Forest of Forestry Faculty of Mulawarman University, Lempake District, Samarinda City, East Kalimantan Province. The study duration was six months, from January to June 2018. The experimental forest covered a total area of 300 ha and was located at 0°25'10"–0°25'24" South latitude and 117°14'00"–117°14'14" East longitude, in between kilometers 10 and 13 of the Samarinda-Bontang Highway. Administratively, this experimental forest is situated in Tanah Merah Village, North Samarinda District, Samarinda City, East Kalimantan Province (KRUS 2013; KRUS 2014).

The study area received 211.5 mm monthly average rainfall, average air temperature is 27.4^{0}C, and relative humidity was 82.2% (Karyati 2015). The average daily temperature and relative humidity inside the forest ranged from 23.7°C to -30.9°C and 81.4% t0 99.3%, respectively. The average daily temperature and relative humidity outside the forest was 25.9°C-28.8°C and 76.0%-90.0%, respectively. The daily average light intensity ranged from 1.08 µmol to 18.41 µmol (Karyati and Ardianto 2016). The climate of Samarinda City was classified as type A climate (a quotient (Q) of 4.8 per cent) based on Schmidt and Ferguson (1951) system which is characterized by highly humidity with a tropical rainforest vegetation (Karyati et al. 2016).

Procedures

Experimental procedures

Experiments were conducted in two 10 m x 10 m experimental plots which were located in areas with two different slope classes inside the experimental forest. One of these two experimental plots had a steep slope (>25-45%) and other had a very steep slope (>45%).

2 m wide terraces were made in each experiental plot. Terrace was completed by ditches sized 25 cm wide and 10 cm depth. Sengon (*F. moluccana*) and long beans (*V. cylindrica*) were planted on both plots. *F. moluccana* trees were planted with a spacing of 3 m × 3 m. *V. cylindrica*, as the intercrop legume, was grown in between the sengon trees. Two erosion measurement plots of 10 m × 3 m size were placed in each of the two experimental plots. The growth paremeters were measured once in every month, for four months period. Plants were maintained by regular watering, weeding, fertilizer application, and pest and disease control. For economic evaluation, only the long beans were harvested, but not the sengon trees. The measurement of hydro-orological parameters were conducted during 27 times rain events.

Analysis of soil properties

The analysis of soil physicochemical properties, such as pH, C organic, total N, P, K, and soil texture, were conducted in Laboratory of Soil Science, Tropical Forest Research Center, Mulawarman University. Soil pH was determined in distilled water and 1 N KCl in a soil to solution ratio of 1:2.5 by the glass electrode method. The C organik and total nitrogen (total N) were analyzed using Walkley and Black method (1934) and Kjeldahl method (1883), respectively. Soil P and K were analyzed using Bray 1 method (1954).

Data analysis

Silvicultural parameters

The observation and measurement of plant growth was conducted at the end of every month for four months. The observation was carried out on both *F. moluccana* and *V. cylindrica* plants. The parameters studied for *F. moluccana* were plant survival rate, tree height, and stem diameter. For *V. cylindrica*, ground coverage and yield was recorded. The plant health was measured for both *F. moluccana* and *V. cylindrica*. A healthy plant was characterized as a plant with a normal height, fresh green leaves, normal stem, and no disease/pests and weed (Ministry of Forestry Republic of Indonesia 2009).

Hydro-orological parameter

The hydro-orological parameters measured in this study were surface runoff, potential soil erosion rate, erosion hazard index, erosion hazard class, and erosion hazard level (Hammer 1981). The erosion hazard index categories and erosion hazard level classification are shown in Table 1 and Table 2, respectively. The erosion hazard index is determined as potential erosion rate (ton ha^{-1} year^{-1})

divided by tolerable erosion rate (ton ha^{-1} $year^{-1}$) (Hammer 1981).

Economic analysis

In this study, the analyzed economic aspects were cost, revenue and profit from long beans as intercropping in sengon (long beans) agroforestry systems. Cost is calculated from price and quantity of inputs, revenue is the price of produced yield, and profit is revenue minus cost (Slavin 2009).

RESULTS AND DISCUSSION

Silvicultural aspects

The recorded plant growth parameters of *F. moluccana* and *V. cylindrica* for the two different slope classes are summarized in Table 3. The growth of *F. moluccana* and *V. cylindrica* combination were "moderate" to "very good" in the steep slope and very steep slope. The survival rate of *F. moluccana* in both slope classes wwas "very good" (90%). The ground coverage of *V. cylindrica* in steep slope was better (80-89%) than in very steep slope (70-79%). Meanwhile, the yield of *V. cylindrica* was also higher (2,500 kg ha^{-1}) in steep slope when compared to the yield in very steep slope (2,100 kg ha^{-1}).

The average of *V. cylindrica* yield in this study was almost similar to the average of Samarinda's yield, but lower than East Kalimantan and Indonesia's yield (Statistics of East Kalimantan Province 2018; Statistics of Indonesia 2018). However, *V. cylindrica*'s yield obtained in this study was lower than reported by Wahyu et al. (2018). Wahyu et al. (2018) reported that the productivity of *V. cylindrica* in Samboja Subdistrict, Kutai Kartanegara District, East Kalimanatn Province was 7,010 kg ha^{-1} and 13,640 kg ha^{-1} from monoculture and agroforestry systems, respectively.

The monthly diameter and height increments of *F. moluccana* trees, measured for four months, are provided in Tables 4 and 5. The stem diameter and height increment of *F. moluccana* trees is faster in the slightly steep slope than in the highly steeper slope. The average stem diameter and height increments of *F. moluccana* were 2.02 cm $year^{-1}$ and 1.54 m $year^{-1}$ in the steep slope, and 1.63 cm $year^{-1}$ and 1.19 m $year^{-1}$, in very steep slope.

The average diameter increment of *F. moluccana* in *F. moluccana* and *V. cylindrica* agroforestry system (on steep and very steep slopes) was lower than those in *F. moluccana* and *Arachis hypogaea* agroforestry system (on slight steep and steep slopes) as reported by Sarminah et al. (2018). On the contrary, the average height increment of this combination was higher than those reported by Sarminah et al. (2018). Similarly, the diameter increment of *F. moluccana* in this study was also lower than those in agroforestry system, monoculture system, and intensive monoculture system (Swestiani and Purwaningsih 2013; Wahyudi and Panjaitan 2013). However, the average diameter increments of *F. moluccana* trees on the steep slope was higher than those planted in the conventional monoculture system (Wahyudi and Panjaitan 2013).

Hydro-orological aspects

The hydro-orological aspects were determined by surface runoff and eroded soil mass. Table 6 presents data regarding rainfall, eroded soil mass, and surface runoff volume in vegetative (*F. moluccana*-*V.cylindrica*) and terrace combination system in the two different slope classes. The result showed that the higher rainfall results in surface runoff and eroded soil mass. Several factors such as rainfall, slope, cover crop, and management practices have suspected influence on soil erosion in the study sites. The length and gradient of slope influences soil erosion. In the steeper slope lands, the rainfall tend to transport the soil particles into lower area faster. It will increase surface runoff and eroded soil mass as well erosion rate. The increasing slope and rain intensity have increased the runoff rate from 20% to 90% (Chaplot and LeBissonnais 2000).

Table 1. Erosion hazard index categories

Erosion hazard index	Category
< 1.00	Low
1,01-4,00	Moderate
4,01-10,00	High
> 10,01	Very high

Source: Hammer (1981)

Table 2. Erosion hazard level classification

Soil column (cm)	Erosion class				
	I	II	III	IV	V
	Erosion rate (ton ha^{-1} $year^{-1}$)				
	<15	15-<60	60-<180	180-480	>480
Deep (>90)	Very low 0	Low I	Moderate II	Heavy III	Very heavy IV
Intermediate (60-90)	Low I	Moderate II	Heavy III	Very high IV	Very heavy IV
Shallow (30-<60)	Moderate II	Heavy III	Very heavy IV	Very heavy IV	Very heavy IV
Very shallow (<30)	Heavy III	Very heavy IV	Very heavy IV	Very heavy IV	Very heavy IV

Source: Regulation of Directorate General of Watershed Management and Social Forestry, Ministry of Forestry Republic of Indonesia (2013). Note: 0=Very low; I=Low; II=Moderate; III=Heavy; IV=Very heavy

Table 3. The growth parameters of *F. moluccana* and *V. cylindrica* in the two different slope classes

Plant species	Steep slope (>25-45%)				Very steep slope (>45%)			
	Healthy plants (%)	Survival rate (%)	Ground coverage (%)	Yield (kg ha^{-1})	Healthy plants (%)	Survival rate (%)	Ground coverage (%)	Yield (kg ha^{-1})
F. moluccana	90 (Very good)	90 (Very good)	-	-	90 (Very good)	90 (Very good)	-	-
V. cylindrica	80-89 (Good)	-	80-89 (Good)	2,500	70-79 (Moderate)	-	70-79 (Moderate)	2,100

Table 4. *Falcataria moluccana* stem diameter increments (mm) in the two different slopes classes

Tree number	Steep slope (>25-45%)					Very steep slope (>45%)				
	D_0	d_1	d_2	d_3	d_4	D_0	d_1	d_2	d_3	d_4
1	12.10	12.85	14.15	16.15	18.68	14.40	15.00	16.05	18.25	21.10
2	9.25	10.00	11.25	12.80	15.00	6.20	6.95	7.90	9.25	11.00
3	8.20	8.90	10.10	11.65	13.85	9.10	9.70	11.00	12.95	15.50
4	5.10	7.80	9.05	10.60	12.50	9.70	10.20	11.25	12.75	15.10
5	12.70	13.65	14.95	16.90	19.25	11.10	11.65	12.90	14.85	17.35
6	8.60	9.55	11.00	12.70	14.75	6.75	7.35	8.30	9.60	11.25
7	5.30	8.00	9.20	10.90	13.00	6.60	7.30	8.40	9.85	11.70
8	7.40	8.15	9.40	11.05	13.00	6.40	7.00	7.95	9.40	11.15
9	10.30	10.90	12.05	13.55	15.50	8.40	9.00	9.95	11.30	13.00
10	10.10	10.80	12.20	13.90	16.10	10.40	11.10	12.15	14.05	16.45
11	5.70	8.50	9.75	11.40	13.55	8.20	8.85	9.80	11.15	12.90
12	10.30	11.20	12.45	14.20	16.60	9.10	10.00	11.50	13.30	15.65
13	11.40	12.10	13.40	15.55	18.20	7.10	7.75	8.80	10.30	12.05
14	6.30	9.10	10.20	12.05	14.15	10.35	11.00	12.20	13.70	15.65
15	10.80	11.50	12.90	14.95	17.55	7.25	8.00	9.10	10.50	12.20
16	4.15	8.75	9.75	11.55	13.65	14.40	15.15	16.50	18.29	20.19
Mean	8.61	10.11	11.36	13.12	15.33	9.09	9.75	10.86	12.47	14.52
SD	2.69	1.81	1.86	1.99	2.17	2.58	2.58	2.66	2.88	3.16
Annual diameter increment	20.18 mm $year^{-1}$ = 2.02 cm $year^{-1}$					Annual diameter increment: 16.27 mm $year^{-1}$= 1.63 cm $year^{-1}$				

Note: D_0 = initial stem diameter (diameter measurement at the beginning of experiment); d_1, d_2, d_3, d_4 = diameter at the end of the first, second, third, and fourth month after planting; SD=Standard Deviation

Table 5. *F. moluccana* height increments (cm) in the two different slopes

Tree number	Steep slope (>25-45%)					Very steep slope (>45%)				
	H_0	h_1	h_2	h_3	h_4	H_0	h_1	h_2	h_3	h_4
1	153	177	189	205	213	176	197	205	210	220
2	144	157	182	194	206	160	173	182	201	205
3	102	106	111	117	125	143	153	157	164	174
4	176	188	196	202	212	124	136	148	155	166
5	165	183	204	212	227	146	163	166	171	176
6	157	172	194	204	212	123	138	145	158	161
7	167	179	187	200	209	145	157	167	176	188
8	146	167	183	192	204	151	165	178	182	194
9	182	205	219	231	242	146	162	166	175	181
10	184	197	208	219	231	164	177	186	199	206
11	116	131	143	159	177	173	185	189	194	208
12	119	136	148	163	176	152	163	169	175	184
13	159	173	183	195	208	119	134	142	154	162
14	168	184	194	212	220	169	186	190	202	214
15	169	185	198	211	221	134	149	158	167	178
16	137	150	163	172	181	101	113	126	136	144
Mean	153	168	181	193	204	145	159	167	176	185
SD	24,10	26,21	27,59	28,10	28,03	21,03	22,03	20,79	20,69	21,48
Annual height increment	153.75 cm $year^{-1}$ =1.54 m $year^{-1}$					Annual height increment: 119.1 cm $year^{-1}$ =1.19 m $year^{-1}$				

Note: H_0 = initial tree height (height measurement at the beginning of experiment); h_1, h_2, h_3, h_4 = height at the end of the first, second, third, and fourth month after planting; SD=Standard Deviation.

Table 6. Rainfall, surface runoff volume, and eroded soil mass in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system in the two different slope classes

Rain event	Rainfall (mm)	Surface runoff (L)		Eroded soil mass (g/30 m^2)	
		Steep slope (>25-45%)	Very steep slope (>45%)	Steep slope (>25-45%)	Very steep slope (>45%)
1	74	46.74	43.40	128.76	111.59
2	37	12.21	46.74	39.93	631.4
3	14	7.87	46.74	13.51	149.74
4	20	7.87	46.74	9.22	164.05
5	41	46.74	46.26	119.22	348.13
6	21	14.95	47.21	47.72	214.6
7	36	46.74	46.74	62.95	147.84
8	22	15.74	46.74	32.75	115.41
9	7	4.72	7.79	4.96	25.43
10	15	6.30	46.74	11.06	97.29
11	13	6.23	15.74	6.49	105.87
12	22	23.37	47.21	14.31	75.35
13	31	46.74	47.21	32.43	61.04
14	49	11.8	46.74	18.12	96.33
15	10	6.3	47.21	2.8	57.23
16	10	6.3	17.92	2.03	15.36
17	17	7.87	46.74	2.07	22.89
18	5	8.66	30.69	0.7	24.18
19	9	4.72	31.48	0.38	8.9
20	14	7.87	46.74	0.16	15.26
21	28	7.87	46.74	2.07	34.34
22	41	14.16	47.21	1.14	14.31
23	42	37.77	47.21	3.05	35.29
24	21	11.02	47.21	1.11	25.75
25	27	11.80	46.74	0.72	16.21
26	10	7.87	47.21	0.16	11.45
27	45	15.74	47.21	0.32	8.58
Total	681	445.92	1132.26	558.13	2633.81
Average	25	16.52	41.94	20.67	97.55

Table 7. The hydro-orological parameters in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system in the two different slope classes

Slope gradient	Surface runoff rate (m^3 ha^{-1} year^{-1})	Potential erosion rate (ton ha^{-1} year^{-1})	Tolerable erosion rate (ton ha^{-1}year^{-1})	Erosion hazard index	Erosion hazard class	Erosion hazard level
>25-45%	305.77	0.38	25[1)]	0.03 (Low)	I (Very low)	Very low
>45%	776.41	1.81	25[1)]	0.13 (Low)	I (Very low)	Vey low

[1)]Soil depth in the study plot was >100 cm and the tolerable erosion rate for hills or slope lands was 25 ton ha^{-1}year^{-1} (Rahim 1995)

Table 8. Comparison of soil erosion reported in the current study with earlier reports for other agroforestry plantation systems

Planting system	Erosion (ton ha^{-1}year^{-1})	Location	Researcher (year)
Soil and water conservation technique and application of agroforestry system	190.08	Ngadipiro Village. Nguntoronadi Sub-district. Wonogiri District. Central Java. Indonesia	Sumarno et al. (2011)
Agroforestry system of *A. cadamba* and *Glycine max*		East Kalimantan. Indonesia	Karyati et al. (2018)
Slope of >15-25%	32.13		
Slope of >25-45%	52.51		
Agroforestry system of *F. moluccana* and *A. hypogaea*		East Kalimantan. Indonesia	Sarminah et al. (2018)
Slope of >15-25%	20.05		
Slope of >25-45%	45.50		
Agroforestry system of *F. moluccana* and *V. cylindrica*		East Kalimantan. Indonesia	Current study
Slope of >25-45%	0.38		
Slope of >45%	1.81		

Table 9. Economic analysis of growing *V. cylindrica* as intercrop in vegetative (*F. moluccana - V. cylindrica*) and terrace combination system in the two different slope classes

No.	Item/activity	Quantity	Unit	Price (Rp)	Total (Rp. $ha^{-1}cs^{-1}$)
Production cost					
Material cost					
1	*F. moluccana* seedlings	1,350.00	units ha^{-1}	3,000.00	4,050,000.00
2	*V. cylindrica* seeds	350.00	units ha^{-1} cs^{-1}	15,000.00	5,250,000.00
3	NPK fertilizer	100.00	kg ha^{-1} cs^{-1}	15,000.00	1,500,000.00
4	Pesticides	25.00	kg ha^{-1} cs^{-1}	30,000.00	750,000.00
5	Plastic strings	1.00	units ha^{-1} cs^{-1}	30,000.00	30,000.00
6	Gunny sacks	20.00	units ha^{-1} cs^{-1}	2,000.00	40,000.00
7	Fertilizer	50.00	units ha^{-1} cs^{-1}	25,000.00	1,250,000.00
	Sub total				12,870,000.00
Depreciation cost					
8	Hoe	2.00	units ha^{-1}	125,000.00	20,833.33
9	Chopper	2.00	units ha^{-1}	100,000.00	16,666.67
10	Sickle	2.00	units ha^{-1}	60,000.00	10,000.00
11	Sprayer	1.00	units ha^{-1}	350,000.00	17,500.00
	Sub total				65,000.00
Labor cost					
12	Land preparation	7.00	days ha^{-1} cs^{-1}	100,000.00	700,000.00
13	Planting	6.00	days ha^{-1} cs^{-1}	100,000.00	600,000.00
14	Fertilizing	4.00	days ha^{-1} cs^{-1}	100,000.00	400,000.00
15	Weeding	5.00	days ha^{-1} cs^{-1}	100,000.00	500,000.00
16	Pest and disease controlling	4.00	days ha^{-1} cs^{-1}	100,000.00	400,000.00
17	Harvesting	6.00	days ha^{-1} cs^{-1}	100,000.00	600,000.00
	Sub total				3,200,000.00
Total cost					16,135,000.00
Total revenue from *V. cylindrica*					
	Steep slope plot (>25-45%)	2,500.00	kg ha^{-1}	8,000.00	20,000,000.00
	Very steep slope plot (>45%)	2,100.00	kg ha^{-1}	8,000.00	16,800,000.00
Profit		Steep slope plot (>25-45%)			3,865,000.00
		Very steep slope plot (>45%)			665,000.00

Note: cs = cropping season

The implementation of vegetative and terrace system was hoped to reduce the potential soil erosion. Generally, the best recommendation for soil and water conservation technology was to combine the vegetative and mechanical systems because such combinations are usually best for reducing soil erosion and decreasing conservation cost in long term as well as increasing short term economical benefits. The *F. moluccana* trees and *V. cylindrica* play a role as cover crop in the sloping lands that could avoid destructive effect of ranfall. In addition, the application of terrace system could reduce surface runoff and increase water infiltration into the deeper soils. Terrace is used to change the slope geometry which become more flater. It is needed in order to improve sloping land stability (Purnamasari et al. 2014).

The erosion rate is also affected by soil properties, especially soil texture. The soil texture in the study site is silty loam that usually support the greatest diversity of plant life. The silt tends to be loaded with the soluble nutrients required by plants. The silt soil also has high content of organic matter. The soil in the study plots was categorized as acidic soil, indicated by the pH value of lower than 5 and the low content of organic C, total N, P, and K. Fine soil grains usually tend to have high erosion risk because they do not form stable soil structures easily because of the fragile cohesion between their particles (A'Yunin 2008).

The evaluation of erosion hazard index, erosion hazard class, and erosion hazard level could be used as an indicator to determine the erosion status in the area. The hydro-orological parameters recorded in this study are shown in Table 7. The tolerable erosion rate for sloping lands is 25 ton $ha^{-1}year^{-1}$ at a soil depth of more than 100 cm (Rahim 1995). The erosion rate of both steep slope and very steep slope plots were less than 15 ton $ha^{-1}year^{-1}$ while the soil depth in the plot was more than 90 cm. The potential erosion rates in steep slope and very steep slope in studied plots were 0.38 ton $ha^{-1}year^{-1}$ and 1.31 ton $ha^{-1}year^{-}$

[1], respectively. The erosion hazard index was 0.03 (low) and 0.13 (low) for steep slope and very steep slope plots, respectively. The erosion hazard classes (class I) and erosion hazard level in both studied slopes belong to "very low" category.

The soil erosion rates recorded in the current study was lower than the values reported for some other agroforestry systems (Karyati et al. 2018; Sarminah et al. 2018; Sumarno et al. 2011) as presented in Table 8. This result implied that the combination of vegetative (*F. moluccana* and *V. cylindrica*) and terrace system could be effectively implemented in different sloping lands.

Economic aspects

The implementation of vegetative (*F. moluccana-V. cylindrica*) and terrace system in different slope classes involves cost expenditure to buy planting and other materials, depreciation on equipments and wages of labor. On the other hand, implementation of this method gives revenue and profit, especially from *V. cylindrica* yield. Table 9 shows economic analysis of *V. cylindrica* as intercrop in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system in the two different slope classes. The material cost involved were for buying *F. moluccana* seedlings, *V. cylindrica* seeds, NPK fertilizer, pesticides, plastic strings, gunny sacks, and fertilizersto increase soil fertility. The profit of *F. moluccana-V. cylindrica* plantation in steep slope was Rp 3,865,000.00 ha^{-1} cs^{-1} and in very steep slope was Rp 665,000.00 ha^{-1} cs^{-1}. This profit was from selling the yield from *V. cylindrica*.

The profit from *V. cylindrica* yield in steep slope was higher than *A. hypogaea* yield on agroforestry system of *F. moluccana-A. hypogaea* as reported by Karmini et al. (2017). The total cost, total revenue and profit related to *F. moluccana* and *A. hypogaea* agroforestry system was Rp 10,985,000 ha^{-1} cs^{-1}, Rp 14,000,000 ha^{-1} cs^{-1} and Rp 3,015,000 ha^{-1} cs^{-1}. However, growing *V. cylindrica* as intercrop in vegetative (*F. moluccana-V.cylindrica*) and terrace combination system in different slope lands is highly benefitial when compared to growing *G. max* in *A. cadamba - G. max* agroforestry system. Karmini et al. (2017) reported that growing *G. max* in *A. cadamba - G. max* agroforestry system involved total cost of Rp 11,019,000.00 ha^{-1} cs^{-1}, total revenue was Rp 3,500,000 ha^{-1} cs^{-1}, and the profit was Rp (-)7,519,000.00 ha^{-1} cs^{-1}.

The implementation of a combination of vegetative and terrace system for soil and water conservation could be applied in the different slope lands. This practice will be benefitial based on silvicultural, hydro-orologica, and economic aspects. The short term economic benefit is provided by agricultural yield from the crop plant. In long term, this practice is benefitial in terms of soil and water conservation and environment aspects. The information of this study on silvicultural, hydro-orological and economic aspects could be used for recommending alternative agroforestry systems in small scale, and soil conservation programs in a wide scale for all stakeholders including farmers, foresters, private parties and the governmental agencies concerned with land management and soil conservation activities.

ACKNOWLEDGEMENTS

The authors wish to express their thanks to Ministry of Research, Technology and Higher Education, Republic of Indonesia for supporting *Hibah Penelitian Strategis Nasional Institusi*.

REFERENCES

ADB. 2016. Indonesia Country Water Assessment. Manila. (PATA 8432-INO). ADB, Mandaluyong City, Philippines.

A'Yunin Q. 2008 Prediksi Tingkat Bahaya Erosi dengan Metode USLE di Lereng Timur Gunung Sindoro. [Skripsi]. Universitas Sebelas Maret. Surakarta. [Indonesian]

Bray RH. 1954. A nutrient mobility concept of soil-plant relationships. Soil Sci 78(1): 9–22.

Budiastuti S. 2013. Sistem agroforestri sebagai alternatif hadapi pergeseran musim guna pencapaian keamanan pangan. Ekosains 5 (1): 1-5. [Indonesian]

Chaplot V, LeBissonnais Y. 2000. Field measurements of interrill erosion under different slopes and plot sizes. Earth Surf Proces Landf 25: 145-153.

Edison, Bisri M, Suhartanto E. 2012. Studi teknologi konservasi untuk menurunkan laju erosi pada Sub DAS Sombe Lewara Provinsi Sulawesi Tengah. Jurnal Teknik Pengairan 3(2): 204–210. [Indonesian]

Hammer WI. 1981. Second soil conservation consultant report. AGOF/INS/78/006. Tech. Note No. 10. Centre for Soil Research, Bogor.

Karmini, Sarminah S, Karyati. 2017. Economic analysis of groundnut (*Arachis hypogaea*) and soybean (*Glycine max*) as intercropping plants in two agroforestry systems. Biodiversitas 18 (2): 483-493.

Karyati. 2015. Pengaruh iklim terhadap jumlah kunjungan wisata di Kebun Raya Unmul Samarinda (KRUS). Jurnal Riset Kaltim 3(1): 51-59. [Indonesian]

Karyati, Ardianto S. 2016. Dinamika suhu tanah pada kedalaman berbeda di Hutan Pendidikan Fakultas Kehutanan Universitas Mulawarman. Jurnal Riset Kaltim 4 (1): 1-12. [Indonesian]

Karyati, Ardiyanto S, Syafrudin M. 2016. Fluktuasi iklim mikro di Hutan Pendidikan Fakultas Kehutanan Universitas Mulawarman. Agrifor 15(1): 83-92. [Indonesian]

Karyati, Sarminah S, Karmini, Simangunsong G, Tamba J. 2018. The mixed cropping of *Anthocephalus cadamba* and *Glycine max* for rehabilitating sloping lands. Biodiversitas 19(6): 2088-2095.

Kjeldahl J. 1883. New method for the determination of nitrogen. Chem News 48(1240): 101–102.

KRUS. 2013. Laporan Tahunan Kebun Raya Unmul Samarinda (KRUS). Tahun 2013. KRUS, Samarinda. [Indonesian]

KRUS. 2014. Laporan Tahunan Kebun Raya Unmul Samarinda (KRUS) Tahun 2014. KRUS, Samarinda. [Indonesian]

Mardaeni, Munir A, Useng D. 2014. Skenario penggunaan lahan untuk mereduksi erosi Berbasis Fuzzy Multi Attribute Decision Making di DAS Jeneberang. J Sains & Teknologi 14(3): 277–284. [Indonesian]

Matatula J. 2009. Upaya rehabilitasi lahan kritis dengan penerapan teknologi agroforestry sistem silvopastoral di Desa Oebola Kecamatan Fatuleu Kabupaten Kupang. Inotek 13(1): 63-74. [Indonesian]

Ministry of Agriculture Republic of Indonesia. 2018. Agricultural Statistics 2018. Ministry of Agriculture Republic of Indonesia, Jakarta. [Indonesia]

Purnamasari DA, Surjandari NS, As'ad S. 2014. Desain terasering pada lereng Sungai Gajah Putih Surakarta. J Matriks Teknik Sipil 2(1): 151-161. [Indonesian]

Rahim SE. 1995. Erosi Tanah dan Pemodelan Pendugaannya dalam Dinamika Lingkungan Hidup Sumatera Selatan. PPLH Lembaga Penelitian Universitas Sriwijaya. [Indonesian]

Regulation of Ministry of Forestry Republic of Indonesia, Ministry of Forestry Republic of Indonesia Number: P.60/Menhut-II/2009. [Indonesian]

Regulation of Directorate General of Watershed Management and Social Forestry, Ministry of Forestry Republic of Indonesia Number: P.4/V-SET/2013. [Indonesian]

Sarminah S, Karyati, Karmini, Simbolon J, Tambunan E. 2018. Rehabilitation and soil conservation of degraded land using sengon (*Falcataria moluccana*) and peanut (*Arachis hypogaea*) agroforestry system. Biodiversitas 19 (1): 222-228.

Schmidt FH, Ferguson JHA. 1951. Rainfall types based on wet and dry period ratios for Indonesia and western New Guinea. Kementrian Perhubungan Djawatan Meteorologi dan Geofisik, Verhandelingen No. 42.

Slavin SL. 2009. Economics. McGraw-Hill Irwin, New York.

Sumarno, Winarno J, Prastomo I. 2011. Kajian pengelolaan lahan berdasarkan tingkat bahaya erosi dan pola konservasi tanah dan air di Desa Ngadipiro Kecamatan Nguntoronadi, Kabupaten Wonogiri. Sains Tanah-Jurnal Ilmu Tanah dan Agroklimatologi 8 (1): 13-22. [Indonesian]

Swestiani D, Purwaningsih S. 2013. Produksi kacang tanah (*Arachis hypogaea* L.) pada agroforestri berbasis kayu sengon dan manglid. Jurnal Penelitian Agroforestri 1(2): 71-82. [Indonesian]

Statistics of East Kalimantan Province. 2018. Kalimantan Timur Province in Figure 2018. BPS Statistics of East Kalimantan Province, Samarinda. [Indonesian]

Statistics of Indonesia. 2018. Indonesia in number 2017. Jakarta: Statistics of Indonesia. [Indonesian]

Tala'ohu SH, Al-Jabri M. 2008. Mengatasi degradasi lahan melalui aplikasi pembenah tanah. J Zeolit Indonesia 7(1): 22-34. [Indonesian]

Wahyu I, Pranoto H, Supriyanto B. 2018. Kajian produktivitas tanaman semusim pada sistem agroforestri di Kecamatan Samboja Kabupaten Kutai Kartanegara. Agroekoteknologi Tropika Lembab 1(1): 24-33. [Indonesian]

Wahyudi, Panjaitan S. 2013. Perbandingan sistem agroforestri, monokultur intensif, dan monokultur konvensional dalam pembangunan hutan tanaman sengon. Prosiding Seminar Nasional Agroforestri 165-171. [Indonesian]

Walkley A, Black IA. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci 37: 29-38.