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Articles

The Role of the Forestry Sector and Processed Forestry Industry on the Economy in West Java, Indonesia

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Abstract

The contribution of the forestry sector is still very small in the West Java region. The continuation of the forestry and processing sector needs attention to improve and develop the sector. This study aims to (1) analyze the role of the forestry sector and wood processing industry (2) analyze the effect of changes in final demand on the output of the forestry sector and the wood processing industry and (3) the right policy formula to develop the forestry sector in West Java. The method used in this study is the input output method supported. The data is sourced from the West Java Regional Development Planning Agency (Bappeda) in the form of a soft copy of the input output table where the year of publication is 2015. The results show the contribution of the forestry sector is only 0.85 % of the agriculture and forestry sector. The wood processing industry only grew by 0.04 % and the forestry sector only grew by 0.01 % if investment had increased between 5–10 %. The role of the forestry sector and wood processing industry can be improved if the government tries to pay attention to regulations that have the potential to overlap which inhibits the growth of investment and licensing of the forestry business and processing industry. The government also needs to involve the community in managing community-based community forestry areas. Benchmark prices need to be regulated to avoid the risk of price uncertainty that can harm society.

Keywords: economy, forestry sector, forestry industry, government.

1. Introduction

The forestry sector in general has not contributed much to economic growth. The contribution of the forestry sector to the GRDP of the agricultural sector was only 0.86 % in 2016. The value even decreased when compared to 2015 which was 0.93 % (BPS, 2019). In detail the contribution of the forestry sector over the past 5 years is presented in Table 1.

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Table 1. Contribution of the forestry sector in the period 2014-2018 forestry

Sector	**2014**	**2015**	**2016**	**2017***	**2018****
Agriculture, Livestock, Hunting and Agriculture Services	88.47	88.19	88.36	87.83	88.18
Food Crops	47.75	48.2	48.63	45.97	47.14
Horticultural Crops	18.55	18.08	18.43	19.38	19.45
Plantation Crops	8.42	7. 72	7.15	7.75	6.92
Livestock	12.23	12.68	12.64	13.22	13.15
Agriculture Services and Hunting	1.52	1.51	1.51	1.51	1.5
Forestry and Logging	0. 96	0.93	0.86	0.86	0.82
Fishery	10.56	10.88	10.78	11.3	10.99
Agriculture, Forestry and Fishery	100	100	100	100	100

Source: BPS, 2019
*provisional numbers
**temporary numbers

The contribution of the forestry sector is still small, indicating that the role of the forestry sector is still very small in the economy of West Java. Indeed, the role of the sector can be optimized if the forest area is utilized by a State-Owned Enterprise together with the community. Purbawiyatna et al. (2012) the policy framework does not yet support sustainable community forest management, especially the clarity of the legal status of forest rights, institutional forest management, forest management techniques and incentive frameworks needed. Communities have economic motives and good perceptions about the importance of the function of forest protection. This can be the capital of the government and a State-Owned Enterprise (BUMN) inviting the community to develop community forests and government forests managed by SOEs.

The West Java Provincial Forestry Service has a Strategic Plan to increase production of forest products. The Forest Service Strategies are (1) Increasing timber production through intensive silviculture systems, (2) Increasing the efficiency of forest product production, (3) strengthening and building commitments of all forestry business actors and (4) increasing marketing of forest products. The strategy to increase wood production through a silvicultural system is formulated into 2 policies, namely (1) increasing knowledge and skills through counseling, education and training on intensive silviculture systems and (2) facilitating agroforestry/social forestry models in forest management. The strategy to increase the efficiency of the production of forest products is implemented through a policy of developing and increasing the efficiency of the processing industry of timber and non-timber forest products. The strategy to strengthen and build the commitment of all forestry business actors is implemented through policies (1) monitoring and evaluation of wood production in state forests and (2) fostering forest product entrepreneurs. The strategy to increase the marketing of forest products is carried out through (1) policies for developing a business network for marketing forest products and (2) promotion of forest products (Dinas Kehutanan, 2013).

Furthermore, local governments have sought economic development of communities around the forest. Perum Perhutani (State-Owned Enterprises) has conducted a populist program called Community-Based Forest Management (PHBM). Etzkowitz and Ranga (2010); Arman et al. (2018) collaboration of government, industry and universities are expected to help in developing the people's economy. This program is very important to revive the hopes of the people who live around the forest. They can voluntarily use the forest area as a sustainable source of the economy. Forest utilization provides added value if the results of forest management are related to the forestry industry. Mattila et al. (2011) the forest industry is closely related to other economies. This happens because the multiplier effect of the supply chain is greater than the origin sector. This shows that the economic system has interdependent relations to various parts (Leontief, 1936).

The forest sector modeling approach seeks to use wood in synergy with the forestry industry and the bioenergy sector consistently (Trømborg, Solberg, 2010). Munday and Roberts (2001) found that forestry and the forestry industry have a degree of interdependence between the rural economy. The wood processing industry has strong links with other parts of the economy. From this analysis, it was concluded that joint development of the forestry and wood processing industries could increase economic development in rural areas (Psaltopoulos, Thomson, 1993). Forestry development in Scotland has very different long-term consequences, especially in terms of output and job creation in rural areas (Thomson, Psaltopoulos, 2005). The wood pellet industry in Vienna contributed to the economy through the creation of a number of workers in the region. Providing the wood waste market as an industrial bio-material can increase the creation of workforce (Joshi et al., 2012). Local governments have a significant opportunity if the value of most of the industrial forest area can be used well managed. This can have a significant influence on rural development and regional development in West Java, Indonesia.

Demand and use of forest resource inputs varies greatly across industrial sectors including for paper products and the furniture manufacturing industry (Chen et al., 2015). This shows that forest management must pay attention to ecosystems to avoid over-exploitation. The Forest Service in the strategic plan also pays attention to ecological-based forest management. Korhonen et al (2001) the Finnish forest industry developed a recycling model for building ecosystems. Industrial ecosystems are built through the flow of matter, nutrition, energy and carbon. Santoso (2006) Extraction of natural resources (forests) should be followed by recovery of nature (forests) to protect the ecosystem.

2. Research Methods

This study uses the input output (IO) method combined with descriptive analysis. Descriptive analysis using secondary data from the Central Statistics Agency (BPS) is supported by a literature review that reinforces the research findings. The OI data used are 2015 data obtained from the Regional Planning Agency (Bappeda). The data is obtained in the form of tabulations and is presented in exel documents. Data calculations use the formulas presented in the exel dashboard. IO data used in this study consisted of 52 sectors. The main sectors discussed in this study are (1) forestry and logging, (2) wood industry, wood and cork goods, woven goods from bamboo, rattan and the like (wood processing industry) and furniture industry. Other sectors discussed are sectors that have close links with other sectors.

Miller and Blair (2009) Leontif lays down 3 basic principles or assumptions on IO, namely (1) linearity, (2) homogeneity and (3) additivity. Linearity requires changes in output caused by changes in proportionality. If it is not proportional, it will have an effect on the excess number of inputs so it is not used in certain sector activities. Homogeneity means that each sector produces a single output with a single input structure (Bureau, 2016). Mathematically IO has matrix nxn, it can be simply presented a technology matrix, Matrix A:

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ a_{31} & a_{32} & \cdots & a_{3n} \\ \vdots & \vdots & \ddots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

Value of $a_{11} \cdots a_{nn}$ on matrix A is the direct input coefficient obtained from equation (2)

$$a_{ij} = \frac{z_{ij}}{x_j} \quad (2)$$

$$Z_{ij} = a_{ij}X_j \quad (3)$$

Furthermore equation (3) can lowered into the new formula into equation (4)

$$\begin{matrix} X_1 = & z_{11} & z_{12} & \cdots & z_{1n} & Y_1 \\ X_2 = & z_{21} & z_{22} & \cdots & z_{2n} & Y_2 \\ X_3 = & z_{31} & z_{32} & \cdots & z_{3n} & Y_3 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ X_n = & z_{n1} & z_{n2} & \cdots & z_{nn} & Y_n \end{matrix} \quad (4)$$

Equation (4) can then be modified to equation (5)

$$\begin{matrix} X_1 = & a_{11}X_1 + & z_{12}X_2 + & \cdots & z_{1n}X_n + & Y_1 \\ X_2 = & a_{21}X_1 + & z_{22}X_2 + & \cdots & z_{2n}X_n + & Y_2 \\ X_3 = & a_{31}X_1 + & z_{32}X_2 + & \cdots & z_{3n}X_n + & Y_3 \\ \vdots = & \vdots & \vdots & \vdots & \ddots & \vdots \\ X_n & a_{n1}X_1 + & z_{n2}X_2 + & \cdots & z_{nn}X_n + & Y_n \end{matrix} \qquad (5)$$

By using algebraic maneuvers, equation (5) can be made at home in equation (6)

$$\underset{\mathbf{A}}{\begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2n} \\ a_{31} & a_{32} & a_{33} & \cdots & a_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{4n} & a_{4n} & \cdots & a_{nn} \end{bmatrix}} \underset{\mathbf{X}}{\begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_n \end{bmatrix}} + \underset{\mathbf{Y}}{\begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \\ Y_4 \\ Y_n \end{bmatrix}} = \underset{\mathbf{X}}{\begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_n \end{bmatrix}} \qquad (6)$$

Equation (6) can be simplified by using matrix notation into equation (7), equation (8) equation (9).

$$\boldsymbol{AX} + \boldsymbol{Y} = \boldsymbol{X} \qquad (7)$$

$$\boldsymbol{X} - \boldsymbol{AX} = \boldsymbol{Y} \qquad (8)$$

$$[\boldsymbol{I} - \boldsymbol{A}]\boldsymbol{X} = \boldsymbol{Y} \qquad (9)$$

The result is equation (10) which results in a matrix multiplier or more dinal with the Leontief Inversion matrix. This matrix describes the exogenous changes that change the value of final demand Y versusoutput. X Furthermore, it can be written in the form of equation notation (10)

$$\boldsymbol{X} = [\boldsymbol{I} - \boldsymbol{A}]^{-1}\boldsymbol{Y} \qquad (10)$$

The magnitude of the change in Y to the change in output $X\, is$ reflected in the delta symbol (Δ). This shows what the value of $\Delta X\, for$ each change in final request is ΔY. Notation can be presented in equation (11)

$$\Delta\boldsymbol{X} = [\boldsymbol{I} - \boldsymbol{A}]^{-1}\Delta\boldsymbol{Y} \qquad (11)$$

IO can record how the interrelationships between input-output. The linkage through two ways, namely backward linkage and forward linkage. The two linkages explain how the effect of (1) an increase in sector i output affects sector output j and (2) an increase in sectoroutput i can increase the distribution of output to the sector itself, namely sector i and other sectors j. If a sector has a backward linkage index and forward linkage index greater than 1, the sector is very good and strategic in improving the economy in West Java. The formula used to produce Backward Linkage Index (IBL) and Forward Linkage Index (IFL) values is presented in equations (12) and equation (13).

$$\boldsymbol{IBL} = \frac{\sum_{i=1}^{n} b_{ij}}{{}^{1}/{}_{n} \sum_{i=1}^{n} \sum_{j=1}^{n} b_{ij}} \qquad (12)$$

$$\boldsymbol{IFL} = \frac{\sum_{j=1}^{n} b_{ij}}{{}^{1}/{}_{n} \sum_{i=1}^{n} \sum_{j=1}^{n} b_{ij}} \qquad (13)$$

3. Results and discussion

Forestry sectors based has not been able to appear as a mainstay sector in West Java. This is reflected in the value of the forestry sector, the wood industry (processing) and the furniture industry having a forward linkage index value of one, only a backward linkage index value of one. These results indicate that the forestry-based sector's production capacity is still small while the inter-sectoral linkages, although quite good, are of relatively small value. The detailed results of the analysis of the forest-based sector are presented in Table 2.

Table 2. Value of Backward Linkage Index and Forward Linkage Index

Sector		BL	Index Backward Linkage	FL	Index Forward Linkage
6	Forestry and Logging	1.216	0.610	1.239	0.622
16	Industrial Wood, Articles of Wood and Cork and Woven Goods from Bamboo, rattan and the like	2.074	1.041	1.821	0.914
25	Furniture Industry	2.555	1.282	1.456	0.731

Results of Table 2 is sufficient to illustrate that the forestry-based sector has not yet become a strategic sector in West Java. Its role is still relatively small when compared to other sectors and industries. Only the wood industry, wood products and woven goods from bamboo, rattan and the like (wood processing industry) which have index value of *backward linkage* more than 1, that is 1.282. These three sectors have index value *forward linkage* of less than 1. These results reflect that the three sectors have not been able to produce greater production output when compared to other sectors. This also reflects that the human resources involved in these activities are relatively small. Furthermore, the production of forest products does not yet have a market buffer, both in the processing sector and in exporting companies.

The other side of the farmers also faces the problem of obtaining high quality seeds. The export market has specifications of the types of quality seeds to produce good wood. Quality wood can only be realized if farmers have quality seeds and good cultivation. Market, human resource and input issues are factors that have caused the forestry sector and the processing industry not to function properly. This issue needs to be addressed by increasing the participation of the Ministry of Forestry in determining the local benchmark wood prices (HPS), by using the export price of logs or international prices. This can increase community income and maximize or protect state revenues from management fees for timber forest products.

Furthermore, industrial business licenses (IIU) are still experiencing problems. These constraints are caused by differences in regulations between the ministry level and the region. The granting of permits for the use of forest products is still considered inefficient because of overlapping authority which results in high costs and permits felt to be long and many costs must be incurred both in the district and province. Astana et al (2014) concerning permit regulation that came from Minister of Forestry Regulation Permenhut.P.11/2008 Regarding the Second Amendment to the Forestry Minister's Regulation Number P.19/Menhut-II/2007 concerning Procedures for Granting Permits and Expansion of Work Areas for Utilizing Timber Forest Products in Industrial Plantation Forests in Plantation Forests in Production Forests (Pemerintah Indonesia, 2018) by the Minister of Agriculture Decree No.357/ KMS/HK.350/5/2002 concerning Settlement of Plantation Business Permits shows a great potential for overlapping (Pemerintah Indonesia, 2002).

The overlap lies in the licensing mechanism of oil palm plantations where there is a clause stating that the granting of permits in one regency / city area through the Regent or Mayor with a copy to the Minister of Forestry. Another regulation states that the issuance of a cross permit through the Governor with a copy to the Minister of Agriculture. The regulation can cause overlapping land management. Land that was originally located in one unit of management area can be difficult for management if the land is to be expanded to manage 2 areas. Overlapping issues can lead to legal uncertainty which results in small investment performance. The small amount of investment causes the sector's leverage to become small. The small leverage with investment and export growth scenarios of 5 % in the wood industry and furniture industries accompanied by investment leverage increases 10 % in the forestry sector is reflected in Table 3.

Table 3. Changes in the leverage of the forestry-based sector with various scenarios

Sector		Initial Output (IDR)	Final Output (IDR)	Growth (%)
6	Forestry and Logging	4,504,150.00	4,555,267.00	0.0112
16	Manufacture of Wood, Goods from Wood and Cork and Woven Goods from Bamboo, Rattan and the like	43,967,624.00	45,831,596.00	0.0407
25	Furniture Industry	14,320,408.00	14,326,102.00	0.0004
31	Trade Cars, Motorcycles and reparation	52,205,041.00	52.259,680.00	0.0010
32	Wholesale and Retail, not Cars and Motorcycles	301,175,758.00	301,457,051.00	0.0009
38	Warehousing and Supporting Services Transport, Postal and Courier	7,005,152.00	7,010,861.00	0.0008
45	ServicesFinancial Support	1,178,755	1,179,790.00	0.0009

Research results show that when the output of forestry and logging sector inventor change became positive and accompanied by an increase in exports by 10 % had an effect on the growth of the wood forestry sector by 0.01 %. The growth of the forestry and logging sector did not have much influence on the performance of other sectors. Although the scenario of investment growth and exports in the forestry sector is very high at 10 %, the effect on other sectors and the forestry sector itself is very small. This means that the contribution of the forestry sector to aggregate economic activity in West Java is still small. Furthermore, the forestry sector does not provide much added value, both to the forestry sector itself and other sectors. This sector only had an influence on the retail trade sector by 0.0009%, the wood goods industry sector by 0.003 %.

But the results are different if the sectors that are encouraged to grow are the wood industry, wood products, and woven goods from bamboo, rattan and the like (wood processing industry) and the furniture industry. Increased investment by 5 %, and exports by 5 % had an influence on the economic growth of the wood processing industry by 0.04 % in the sector. The influence of the growth of the wood processing industry has broad implications for various economic sectors in West Java. The sectors that gained the most influence were the forestry and logging sectors by 0.01 %. This shows that the forestry sector can grow well if the government encourages investment and exports of the manufacturing industry accompanied by the growth of private consumption in the sector. Growth in private consumption in the wood processing industry is very possible because investment growth of 5 % can have an influence on employment and value added of labor wages.

The growth of the furniture sector is apparently not so influential with an increase in exports and investment of 5 %. The sector can only grow by 0.004 %. This gives a signal that the furniture industry is not yet large in economic relations with the wood processing industry and the forestry sector. The growth of the industrial sector more affected the large trade sector by 0.0009 %, the warehousing and transportation services sector by 0.0008 %, financial support services by 0.0009 % and the car trade sector by 0.001 %.

The wood processing and forestry industry has an important role and contribution to several economic sectors in West Java. Although small in number but the forestry industry has links with several sectors. This shows that the manufacturing sector has quite a wide spread effect, although its value is small. The size is influenced by the volume of production. If the production volume is large, it can produce a fairly large spread of power.

The contribution of the forestry sector is still very small towards the economy of West Java. The economic prospects of Jabon and Sengon plants are quite good, but the market constraints are still relatively limited. Furthermore, the relatively large amount of investment and the long waiting period for the harvest meant that farmers who had limited capital were unable to develop Jabon and Sengon cultivation. Cultivation of forestry plants is more developed for large enough capital owners. This is one of the reasons that the cultivation of forestry plants is small so that the effect on economic activities is also small.

The government needs to optimize the use of production forest land and cultivation land to develop the forestry and logging sector as well as the processing industry. The management of log industry and trade is based on ministerial regulation 55/Menhut-II/2006 concerning the administration of forest products originating from state forests.

The scale of the forest processing business based on the research results of Astana et al (2014); Sari (2016) is still very economically feasible. This shows that the forestry sector is able to overcome social problems and provide solutions to development. The government needs to synergize the management and processing of forests between entrepreneurs and the community. Industrial Forest Land owned by State-Owned Enterprises (BUMN) can be managed by utilizing the community around the forest. Their involvement is expected to reduce the risk of forest encroachment, on the other hand increase community income. Community-based community involvement where they are not only involved as workers but as managers. The government provides assistance especially in terms of maintenance and cultivation to marketing. This pattern can increase the existence of state-owned companies and increase people's income and reduce social problems. Utilization of state-owned forests has been realized as the findings of Panlevi (2019) where land owned by Nusantara VII Limited Company (PTPN) was lent to the surrounding community to be managed on a community-based basis. The community conducts cultivation and development of Ciwaluh coffee in Bogor, West Java. The use of the land is to maintain the function of the forest as well as to build community youth communities to have jobs. The land is managed voluntarily and all profits are left to the community.

In addition to increasing land use optimally, the government also needs to develop a wood processing industry. The wood processing industry has economic links with various sectors. Increased output of the wood processing industry can revive other economic activities such as the financial services sector, trade, warehousing, transportation services and forestry. This shows that the development of the forestry sector must be done in parallel with the processing industry and the study of legislation. The government must conduct a review of legislation to address regulatory issues that can "hinder" investment. Inter-ministerial regulations must in fact be synergistic in order to avoid legal problems. Legal certainty and legal protection are important instruments to guarantee the implementation of investments, workers' rights and environmental sustainability. There are many regulations that need to be integrated between regulations relating to forestry, the environment and the workforce.

4. Conclusion

The forestry sector and wood processing industry in West Java have not contributed much to development. Its contribution is still very small compared to the agricultural sector. The wood processing industry only grew by 0.04 % and the forestry sector only grew by 0.01 % if investment had increased. This low growth shows that the economic activity of the forest processing sector and industry has little effect. Furthermore, low growth in the forestry sector and wood processing industry still has hope in helping the economy of West Java. The growth of the manufacturing industry has an influence on the growth of the sectors of transportation, warehousing, financial services and trade.

The role of the forestry sector and wood processing industry can be improved if the government tries to pay attention to regulations that have the potential to overlap which inhibits the growth of investment and licensing of the forestry business and processing industry. The government also needs to involve the community in managing community-based community forestry areas. Community participation in forest management can reduce illegal forest encroachment, on the other hand increase community income. Benchmark prices need to be regulated to avoid the risk of price uncertainty that can harm society. The price benchmark is intended so that profits can be received by the public and companies. This effort can increase the role of the power sector in the economy of West Java.

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Remote Sensing Application in Mapping Agricultural Crop Areas and Monitoring Rice Maturity

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Abstract

Climate change has evolved in an unpredictable trend and droughts have occurred more and more severely in the central provinces of Vietnam. Determining the irrigated area and water requirement for various crops and the growth stage of each crop is an urgent need as water resources for irrigation are getting scarce year by year. This research examines the application of Sentinel-2 and Sentinel-1 images to map crop areas and identify the current development stage of paddy rice areas. The images are collected and pre-processed from 2017 to 2018 for Ha Tinh Province in Vietnam. The Maximus Likelihood method is used to interpret Sentinel-2 imagery for mapping agricultural crop distribution status. The research presents a new approach for identifying rice maturity using the Sentinel-1 image series. The Overall Accuracy (OA) and Kappa coefficient methods are used to evaluate the generated maps of the agricultural crop's distribution status. This study shows the relationship between the Sentinel-1 VH band and the growth of rice. From the image bands, we could calculate the slope of the line correlating between the VH backscattering value and the growth time of rice. Along with the local planting schedule, rice life cycle, and simple deduction, we could determine the rice growth stage at each time of image acquisition. The result will be the input parameter for the irrigation management, monitoring and operating information system that is applied to Ha Tinh province for proper and effective irrigation. The results identifying the rice maturity progression are illustrated for Cam Hoa commune in Cam Xuyen district and Thach Hoi commune in Thach Ha district, Ha Tinh Province.

Keywords: remote sensing, map of agricultural crop, rice maturity.

1. Introduction

In recent years, climate change has evolved in an unpredictable trend and droughts have occurred more and more severely in the central provinces of Vietnam. Determining the irrigated area and water requirement for various crops and the growth stage of each crop is an urgent need as water resources for irrigation are getting scarce year by year.

Various studies have used free satellite imagery to map crop classification. For example, a crop classification map for a province of Valencia (Spain) was obtained from the Sentinel-1 and Sentinel-2 data using the decision tree method with an accuracy of 93.96 % (Manuel et al., 2019); applying the Random Forest (RF) algorithm on Sentinel-2 and Landsat-8 data in semi-arid

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environments in the Eastern Mediterranean (Stavros Patsalidis et al., 2019); Using the Maximum Likelihood (MLC), Support Vector Machine (SVM), RF method to produce crop distribution maps from Sentinel-2, Landsat-8 (Raziye Hale et al., 2016; Neetu et al., 2019; Licheng Zhao et al., 2019; Tian-Xiang Zhang et al., 2019); Accurate classification for Land use and land cover maps using SVM algorithm on Sentinel-2 to analyze the data (Cavur et al., 2019; Immitzer et al., 2016).

Conventional optical images were affected by cloud cover and thus, the use of radar images to determine the growth stage of the rice has captured the attention of many researchers. For instance, using Monte Carlo simulation with RADARSAT data to predict rice maturity (Wang et al., 2005); Using ENVISAT/ASAR data to establish a rice map for the Mekong Delta in Vietnam, piloted in An Giang province with an overall accuracy of 85.3 % and the kappa coefficient of 0.74 (Bouvet et al., 2011; Nguyen et al., 2015) and a series of studies using radar satellite images to map rice distribution (Lopez-Sanchez et al., 2011; Nelson et al., 2014; Clauss et al., 2018; Lasko et al., 2018; Ndikumana et al., 2018). In addition, a group of authors used machine learning algorithms training Sentinel-1 data to identify the rice, its yield, and height. The study was conducted in the Camargue region, southern France. Height and biomass of rice were calculated based on Sentinel-1 data trained by machine learning algorithms, Multiple Linear Regression (MLR), Support Vector Regression (SVR) and RF. The results showed that the correlation between the polarization of VH Sentinel-1 and biomass is also very high with R2 = 0.9 and RMSE = 18 % (162 g·m-2) (with RF method) (Ndikumana et al., 2018). Using a combination of Gaussian distribution, VV/VH variance and slope coefficient of the linear regression equation of the VH series of Sentinel-1 imagery was performed for crop mapping. The overall accuracy obtained was 96.3 % by using the decision tree and 96.6 % by using the RF classification (Hassan Bazzi et al., 2019).

The above studies focused on rice mapping for the whole crop development. The algorithm for determining rice maturity is not feasible when applied on such large scales as a province or a country in a short period of time. This study focuses on the use of Sentinel-2 imagery data to map agricultural crop areas and the use of Sentinel-1 image series data to determine the current growth stage of rice cultivation areas. A new approach for determining rice maturity using the Sentinel-1 SAR series in Ha Tinh province, Vietnam is proposed. Identified rice and other crop cultivation areas and its growth stages at a certain period is a useful source of information to improve irrigation efficiency in Ha Tinh province. The paper is structured in the following main sections, after a description of the study site and data availability in section 2.1, the proposed methods are presented in section 2.2. The results and discussion are presented in section 3 and the main conclusions are presented in section 4.

2. Methods and Data

2.1. Research Design

First, a field trip was conducted to identify the interpretation key of rice, vegetable, forest, and other crops for Sentinel-2 imagery. Using the Maximums Likelihood method was employed to classify plants based on the interpretation key, then filtering out the noise using the Majority method. The backscattering coefficient at VH of Sentinel-1 images is related to the growth of rice height. The slope of a straight line shows the variable relationship between the change in the VH backscattering value which represents the change in rice height (Δy) and the change in rice growth stages (Δx) which is determined in each image capture cycle. Finally, we make use of the planting schedule and the series of image bands of slope values to analyze the growth stage of rice. Only Sentinel-1 pixels within the boundaries of the rice growing areas identified from the Sentinel-2 imagery are used for rice maturity analysis. Each crop has a different coefficient of water use and each growth stage of the crop requires different water usage.

2.2. Data

The Sentinel-2 optical imagery data at 1C was collected from the European Space Agency (ESA) image database at the website https://scihub.copernicus.eu/dhus/ and the radar images of Sentinel-1 composite aperture, C band, Interferometric wide-swath mode image acquisition, 250 km, 5 × 20 m resolution at Ground Range Detected (GRD) Level 1 were collected at the following address https://search.asf.alaska.edu/. Images were collected in 2017 and 2018 for Ha Tinh province.

2.3. Methods

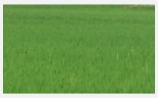
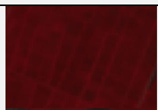
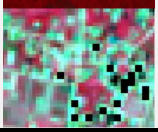
a) Pre-Processing Satellite Images. Beyond observing demographical data, the questionnaire was to explore the use, motivation for and effect on physical activity of wearable activity trackers as well as the technical parameters of using the device. During the survey CAWI (Computer-Assisted Web Interviewing) method was applied. The recruitment was carried out partly at university courses and partly on e-learning interface, where we placed the link directing to the questionnaire. Sentinel-2 optical imagery at level 1C has been processed with spectral radiation and orthogonal image correction. After being downloaded from ESA's database, the image was converted from level 1C to 2A which is a level where errors due to atmospheric, topographic, haze effects were removed and preliminary classification of the land cover was performed with sen2cor tool (http://step.esa.int/main/third-party-plugins-2/sen2cor). 2A-level Sentinel-2 products were resampled to have a uniform resolution for image bands. The study area of Ha Tinh province was created as a subset and the reference system was converted to the EPSG: 3405 reference system of Vietnam using SNAP Desktop, an open-source code software provided by ESA.

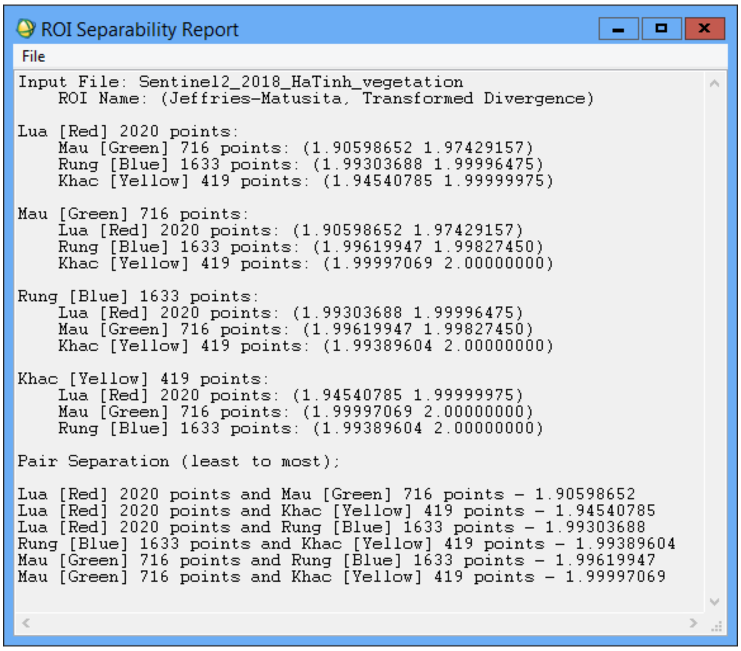
Sentinel-1 Level-1 IW GRD images were detected, multi-looked and projected to the ground range using an Earth ellipsoid model. After being downloaded from the database, the image was calibrated, speckle filtered and corrected for the influence of the terrain (Range-Doppler Terrain Correction). The study area of Ha Tinh province was created as a subset and the reference system was converted to the EPSG: 3405 reference system of Vietnam using SNAP Desktop software.

b) Interpretation of Free Sentinel-2 Optical Satellite Images for Mapping the Status of Agricultural Crop Distribution. Sentinel-2 images were interpreted by the Maximus Likelihood method, a method of classification with the inspection. The input variable for this method is a key list that interprets objects such as rice, vegetable, forest and other crops (Table 1). To develop the interpretation keys, we conducted a field trip to sample the objects to be classified. ENVI software is used to run the classification algorithms. Figure 1 is the notification window showing the results of verifying the object separability in image interpretation keys in Ha Tinh province in 2018. Classification results will be noise-filtered by the Majority method.

Sentinel-2 images taken in Ha Tinh province are significantly affected by the cloud. The Sen2Three tool is an extension of SNAP Desktop, using a series of Sentinel-2 images to eliminate cloudy pixels and replace them with clearer pixels.

Table 1. Interpretation key of rice, vegetable, forest and other crops on Sentinel-2 imagery and in the field

No.	Object	Field sample	Sample of Sentinel-2 images with color combination bands 3-4-8
1	Rice		
2	Vegetable	 	 
3	Forest		
4	Other crops		



```
ROI Separability Report
File
Input File: Sentinel2_2018_HaTinh_vegetation
    ROI Name: (Jeffries-Matusita, Transformed Divergence)

Lua [Red] 2020 points:
    Mau [Green] 716 points: (1.90598652 1.97429157)
    Rung [Blue] 1633 points: (1.99303688 1.99996475)
    Khac [Yellow] 419 points: (1.94540785 1.99999975)

Mau [Green] 716 points:
    Lua [Red] 2020 points: (1.90598652 1.97429157)
    Rung [Blue] 1633 points: (1.99619947 1.99827450)
    Khac [Yellow] 419 points: (1.99997069 2.00000000)

Rung [Blue] 1633 points:
    Lua [Red] 2020 points: (1.99303688 1.99996475)
    Mau [Green] 716 points: (1.99619947 1.99827450)
    Khac [Yellow] 419 points: (1.99389604 2.00000000)

Khac [Yellow] 419 points:
    Lua [Red] 2020 points: (1.94540785 1.99999975)
    Mau [Green] 716 points: (1.99997069 2.00000000)
    Rung [Blue] 1633 points: (1.99389604 2.00000000)

Pair Separation (least to most);

Lua [Red] 2020 points and Mau [Green] 716 points - 1.90598652
Lua [Red] 2020 points and Khac [Yellow] 419 points - 1.94540785
Lua [Red] 2020 points and Rung [Blue] 1633 points - 1.99303688
Rung [Blue] 1633 points and Khac [Yellow] 419 points - 1.99389604
Mau [Green] 716 points and Rung [Blue] 1633 points - 1.99619947
Mau [Green] 716 points and Khac [Yellow] 419 points - 1.99997069
```

Fig. 1. The sample verifying the object separability in the 2018 image interpretation key – Interpretation of Sentinel-1 free radar satellite imagery to determine rice maturity

Sentinel-1 images provide two backscattering values, VV and VH. In this study, we use VH backscattering, which is sensitive to the crop height. VH backscatter values of radar images have different values as they are affected by different rice varieties, rice yield of each region, the topography of rice cultivating areas and the effect of speckled noise. Therefore, it is not feasible to track the set of VH values in a rice crop to identify the rice patterns. Considering a rice crop, taking the X-axis as the time of capturing the image and the Y-axis as the VH backscattering values of the pictures taken, the first point is at the starting time of sowing/transplanting and the endpoints are image capturing moments later. Thus, it is possible to define a series of straight lines with the equation y = ax + b. Using simple linear regression, we can determine coefficients a and b.

Assume we have n image capturing cycles from cycle 0 to cycle n-1.

Combining cycle 0 with cycle 1, we have a line $y_1 = a_1x+b_1$

Combining cycle 0 with cycle 2, we have a line $y_2 = a_2x+b_2$

Combining cycle 0 with cycle n-1, we have a line $y_{n-1} = a_{n-1}x+b_{n-1}$

The coefficient represents the variable relationship between the change in VH backscattering value that describes the change in rice height (Δy) and the change in growth time of rice (Δx). For each pixel, there is a sequence of values a_1, a_2, ..., a_{n-1}. The values of these coefficients are recorded to the image bands $Slope_1$, $Slope_2$, ..., $Slope_{n-1}$, respectively.

Combining the RGB color scheme between these Slope image bands, users will see the rice's change in height, thereby are able to interpolate the growth stage of the rice plant. The accuracy of this method is limited and the author group is working on improving its accuracy gradually.

Evaluating the results of interpreting Sentinel-2 images to map current agricultural crop distribution status

The method of evaluating the results of image interpretation uses error matrix and is implemented on ENVI image processing software. The two methods used are the Overall Accuracy (OA) method (1) and the Kappa Coefficient (Kappa Coefficient) method (2).

The OA is determined using the following formula:

$$OA\ (\%) = 100 * \frac{The\ number\ of\ pixels\ that\ were\ correctly\ classified}{Total\ number\ of\ pixels\ in\ the\ classification\ sample} \quad (1)$$

The Kappa coefficient is determined using the following formula:

$$K = \frac{n\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} * x_{+i})}{n^2 - \sum_{i=1}^{r}(x_{i+} * x_{+i})} \qquad (2)$$

In which:
n is the total number of pixels,
x_{ii} is the pixel on the diagonal of the matrix (correctly classified pixels),
x_{i+} is the total number of pixels in rows,
x_{+i} is the total number of pixels in the columns.

3. Results and discussion

3.1. Results of Mapping the Distribution of Crops (Rice, Vegetables) Based on Sentinel-2 Images

Sentinel-2 image data collected in Ha Tinh province on March 5, 2018 (T48QWF) and May 16, 2018 (T48QWF, T48QXF) were used to map crop distribution using the Maximums Likelihood (Figure 2). The area of rice and vegetable crops was interpreted from the Sentinel-2 imagery in 2018 comparing to the crop area statistics shown in Table 2.

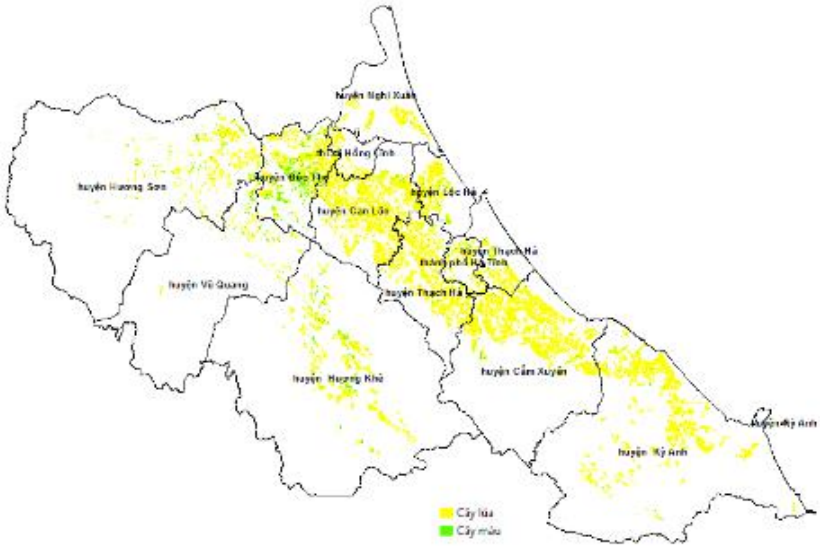


Fig. 2. 2018 rice and vegetable crops distribution map layer (Yellow = rice, green = vegetables)

Table 2. Comparison of the interpretation results of rice and vegetable cultivating areas with referenced crop areas

Year	Interpretation Object	Area interpreted with Sentinel-2 imagery (hectares)	Referenced crop areas from Ha Tinh province (hectares)
2018	Rice	64,014	59,143
	Vegetables	10,049	14,504

Verifying that the results of 2018 Sentinel-2 image interpretation has a Kappa coefficient of 0.89 and an OA of 92.42 %.

3.2. Results of Rice Crop Progression in Sentinel-1 Imagery

In order to verify the results of determining the rice maturity, Cam Hoa commune, Cam Xuyen district and Thach Hoi commune, Thach Ha district, Ha Tinh province are examined. An image series captured the winter-spring rice crop in 2018 includes 13 Sentinel-1 image cycles on January 14, January 26, February 7, February 19, March 3, March 15, March 27, April 8, April 20, May 2, May 14, May 26, and June 7, 2018, corresponding to the stages of growth and development of rice from February 6 to June 4, 2018. 12 image bands $Slope_1$, $Slope_2$,... to $Slope_{12}$ are produced. In Figure 3, the Product Explorer tab contains 12 images, the main screen opens 12 images simultaneously from $Slope_1$, $Slope_2$, ... to $Slope_{12}$, which makes it easy to see that the growth of rice changes gradually over time. Table 3 is a summary of results from the local planting calendar, rice-growing stages and color combination of image bands in Figure 3.

Table 3. Tables may span across both columns

No.	Sentinel-1 image time (2018)	Number of days	Growth and development stage	Slope band
1	14/1-7/2	0	Tilting the soil and wetting the field	
2	26/1-19/2	12	Wetting the field until sowing	1, 2, 3
3	7/2-3/3	24	Sowing to tillering	2, 3, 4
4	19/2-15/3	36	Tillering	3, 4, 5
5	3/3-27/3	48	Tillering to leaf stem development	4, 5, 6
6	15/3-8/4	60	Leaf stem development	5, 6, 7
7	27/3-20/4	72	Leaf stem development and panicle formation	6, 7, 8
8	8/4-2/5	84	Panicle formation	7, 8, 9
9	20/4-14/5	96	Flowering	8, 9, 10
10	2/5-26/5	108	Flowering to ripening	9, 10, 11
11	14/5-7/6	120	Ripening to harvesting	10, 11, 12
12	7/6	120	Completed harvest	12

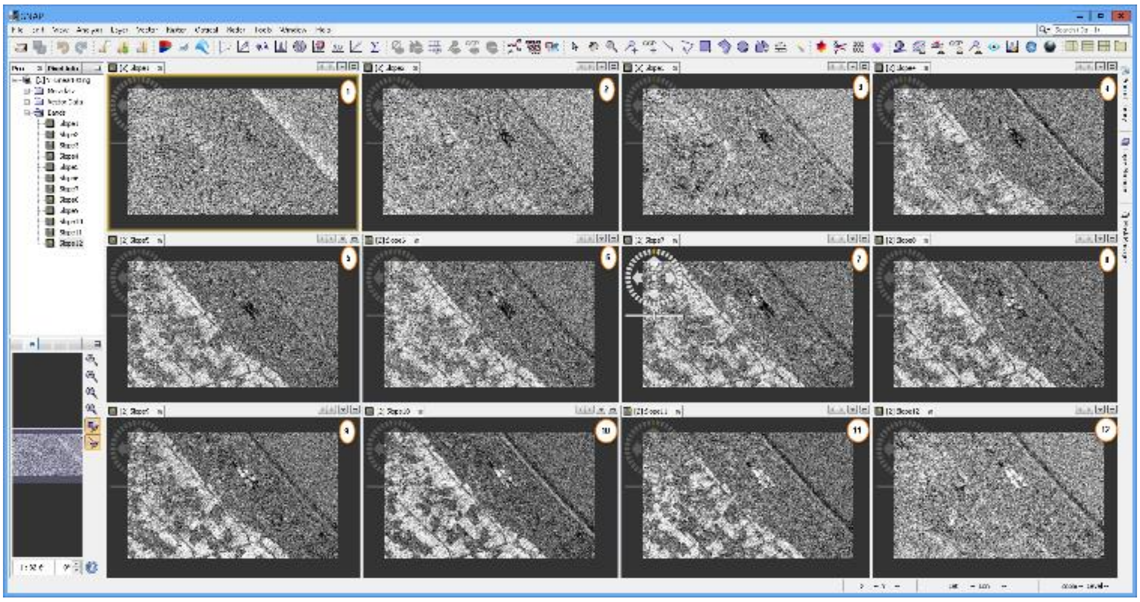


Fig. 3. Rice growth images through 12 Slope bands

To see the changes more clearly, the colors for three that represents the times of rice growth and development stages. Specifically, Slope$_1$ corresponds to Red, Slope$_2$ corresponds to Green, and Slope$_3$ corresponds to Blue.

Figure 4 shows the result of the color combination of Slope$_1$, Slope$_2$ and Slope$_3$ image bands from January 14 to February 19, 2018. This was the time for tilting the soil and bringing water into the rice field. Area 1 has rice on the field and rice has not appeared on area 2 yet.

Figure 5 demonstrates the result of the color combination of Slope$_2$, Slope$_3$ and Slope$_4$ image bands from February 7 to March 3, 2018. This was the time when the rice crop is still low compared to the water level in the field. Area 1 has rice in the field while area 2 appears purple which is the watercolor brought into the field with sowing/transplanting in the field.

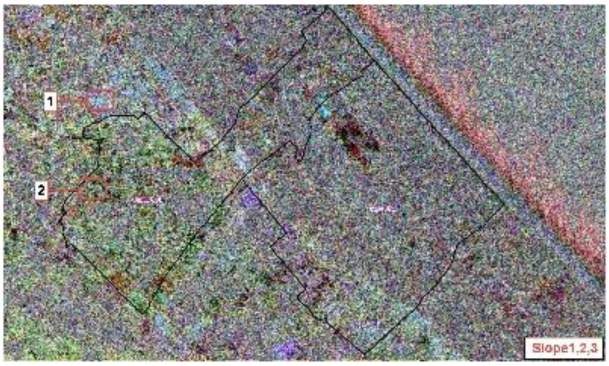


Fig. 4. Color combination of $Slope_1$, $Slope_2$ and $Slope_3$ image bands

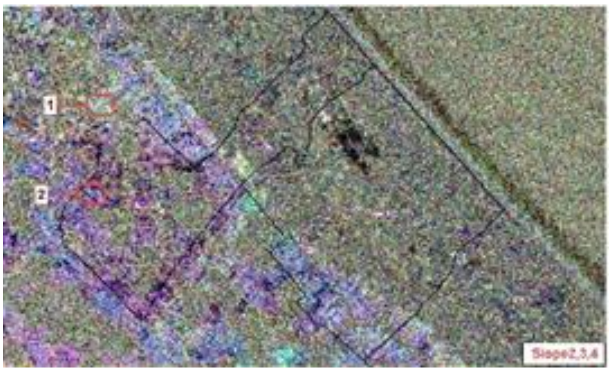


Fig .5. Color combination of $Slope_2$, $Slope_3$ and $Slope_4$ image bands

Figure 6 shows the results of the color combination of $Slope_3$, $Slope_4$ and $Slope_5$ image bands from February 19 to March 15, 2018. This was the time of rice growing in height, area 1's rice has moved to a new stage, area 2 has clearly recognizable rice in the field – the stage of sowing/transplanting to tillering.

Figure 10 exhibits the result of the color combination of $Slope_7$, $Slope_8$ and $Slope_9$ image bands from April 8 to May 2, 2018. At this time, the rice is tall and is in a good development stage.

Figure 11 presents the result of the color combination of $Slope_8$, $Slope_9$ and $Slope_{10}$ image bands from April 20 to May 14, 2018. Across the study area, the combined color values are quite homogeneous, which means that this is the period when the rice is at the best consecutive Slope moments are combined to form a map layer development-stage-flowering.

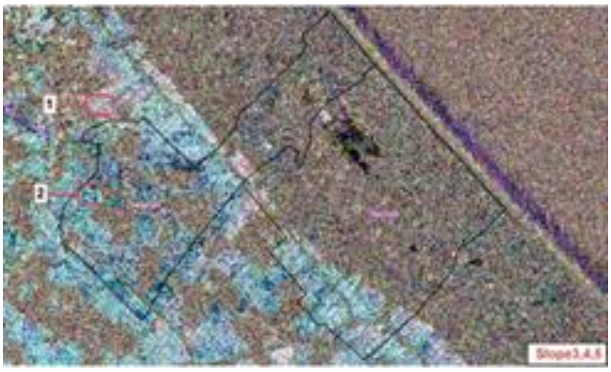


Fig. 6. Color combination of $Slope_3$, $Slope_4$ and $Slope_5$ image bands

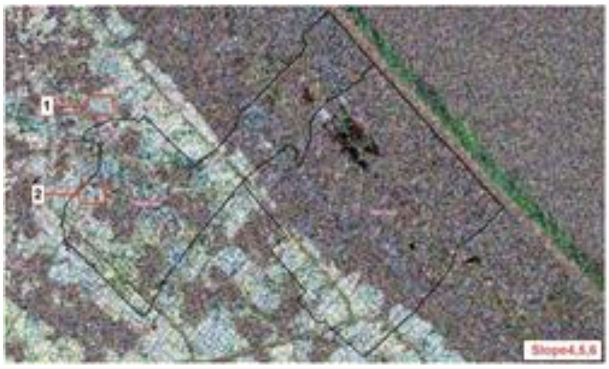


Fig. 7. Color combination of $Slope_4$, $Slope_5$ and $Slope_6$ image bands

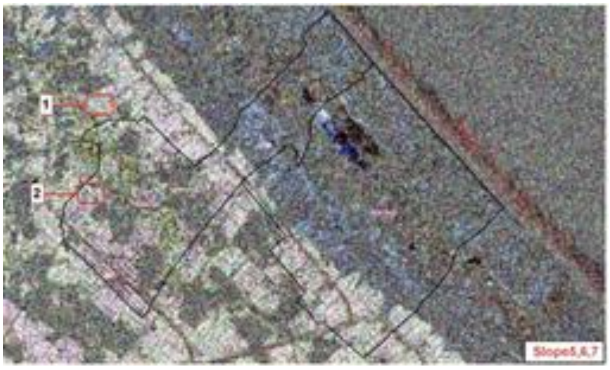


Fig. 8. Color combination of $Slope_5$, $Slope_6$ và $Slope_7$ image bands

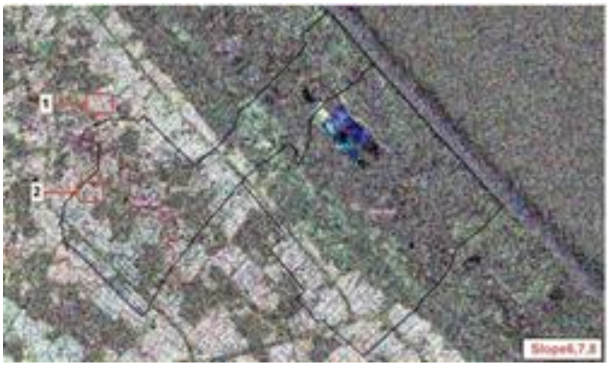


Fig. 9. Color combination of $Slope_6$, $Slope_7$ và $Slope_8$ image bands

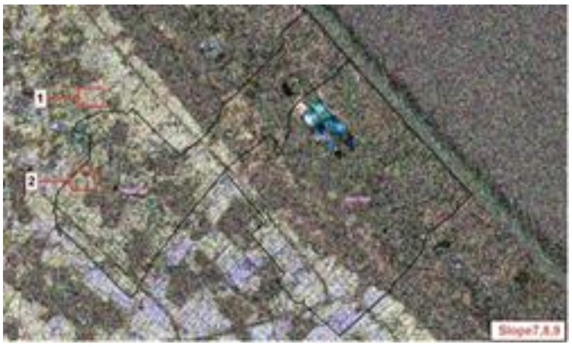


Fig. 10. Color combination of $Slope_7$, $Slope_8$ and $Slope_9$ image bands

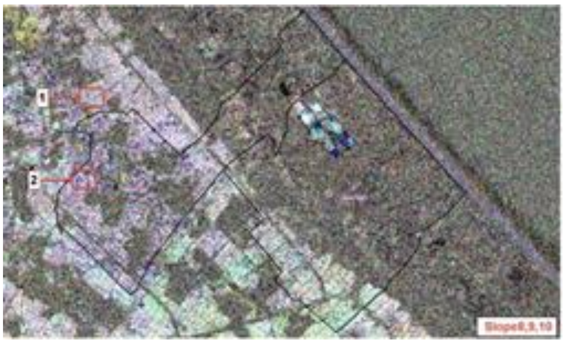


Fig. 11. Color combination of $Slope_8$, $Slope_9$ and $Slope_{10}$ image bands

Figure 12 shows the result of the color combination of $Slope_9$, $Slope_{10}$ and $Slope_{11}$ image bands from May 2 to May 26, 2018. Rice enters the ripening stage, the color of the combination changes significantly compared to that in Figure 11.

Figure 13 indicates the results of the color combination of $Slope_{10}$, $Slope_{11}$ and $Slope_{12}$ image bands from May 14 to June 7, 2018. Area 1 has harvested rice (dark pink), area 2 has rice at the stage of fully ripe to being harvested. The $Slope_{12}$ image band in Figure 3, taken on June 7, 2018, shows that all the rice plants have been harvested.

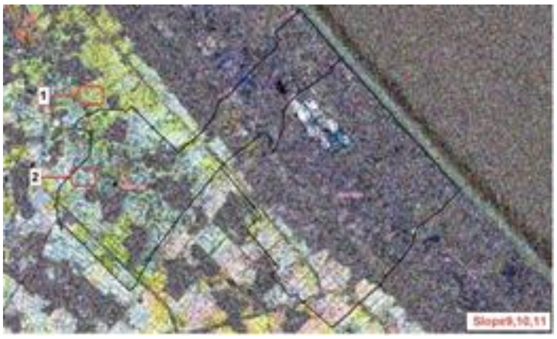


Fig. 12. Color combination of $Slope_9$, $Slope_{10}$ and $Slope_{11}$ image bands

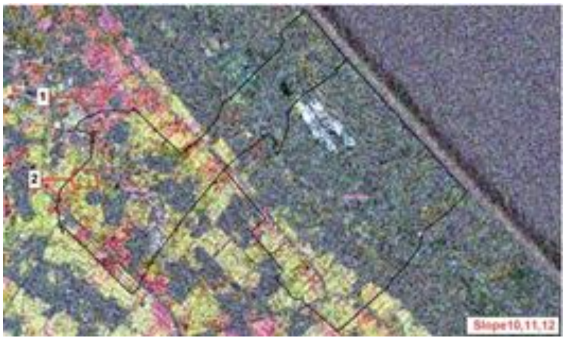


Fig. 13. Color combination of $Slope_{10}$, $Slope_{11}$ and $Slope_{12}$ image bands

3.3. Field Verification and Supplementation of Industrial Results Interpreting Satellite Images Identifying Agricultural Crops

Field survey

Identify sampling points (Figure 14), a GPS device was to delineate the area of crops (rice, crops) in the field, capture the entire landscape around the sampling area on the camera. (Figure 15).

Fig. 14. Field survey and GPS positioning of vegetable crop areas in Xuan Linh commune, Nghi Xuan district

Fig. 15. Locations of sampling points for agricultural crops (rice, vegetables)

Calibrate and verify the results of image interpretation for identifying agricultural crops

The survey locations of crops (rice, vegetables) were compiled and edited in the form of a map (.shp) where incorrect positions were corrected directly on the agricultural crop map. (.shp) from the satellite image background.

The accuracy of the map established from satellite images is computed using an error matrix. The matrix of errors is made based on comparing the results of indoor interpretation with the results of field surveys. This matrix is a square matrix with the order equals the number of layers sorted and verified. The header row of the columns (top row) shows the names of verified classes. The title column of the row (the first column) shows the names of the classified classes. The diagonal line from the top left to the bottom right of the matrix records the number of pixels or classified objects that coincide with the actual verification (exact classification). The remaining cells of the matrix record the number of pixels or objects with the following characteristics: according to the classification results, they belong to the class recorded on the column, but in fact they are verified to belong to the class recorded in the header of the row. They show the classification error and are divided into two types: errors by omission and errors by redundant inclusion.

The total classification error is calculated by dividing the total number of correctly classified pixels (i.e the total diagonal value of the matrix) by the total of classified and verified pixels. The error for each layer is calculated by dividing the total pixels of that layer with the total pixels by row or column. The ratio of the total number of correct pixels for a layer divided by the total number of pixels in a column is called error by omitting classification. The ratio of the total number of correctly classified pixels in a layer divided by the total number of pixels classified into that group by the line is called redundancy error. Table 4 shows the evaluation by Kappa coefficient.

Table 4. Kappa coefficient rating

Rating	Kappa coefficient
Very good	≥ 0.81
Good	0.80 – 0.61
Average	0.60 – 0.41
Low	0.40 – 0.21
Bad	0.20 – 0.0
Very bad	< 0.0

3.4. Survey and Verify the Results of Image Interpretation for Identifying the Stage of Rice Growth

To verify the results of Sentinel-1 image interpretation to monitor the growth and development of rice (rice stage), we serveyed in the Cam Hoa commune, Cam Xuyen district and Thach Hoi commune, Thach Ha district, Ha Tinh province and evaluate the results in the study area (Figure 16): Three times in a rice crop, at critical times of the rice: sowing to tillering; panicle formation to flowering; ripening to harvesting; Measure the height of the rice plant at 20 points in the field corresponding to three important times of rice (Figures 17, 18, 19); Assess the accuracy between the height of the rice measured and the Slope value at the time of the rice stage from sowing to tillering with R^2 = 0.92 (Figure 20) and at the time of the rice stage from panicle formation to flowering with R^2 = 0.93 (Figure 21).

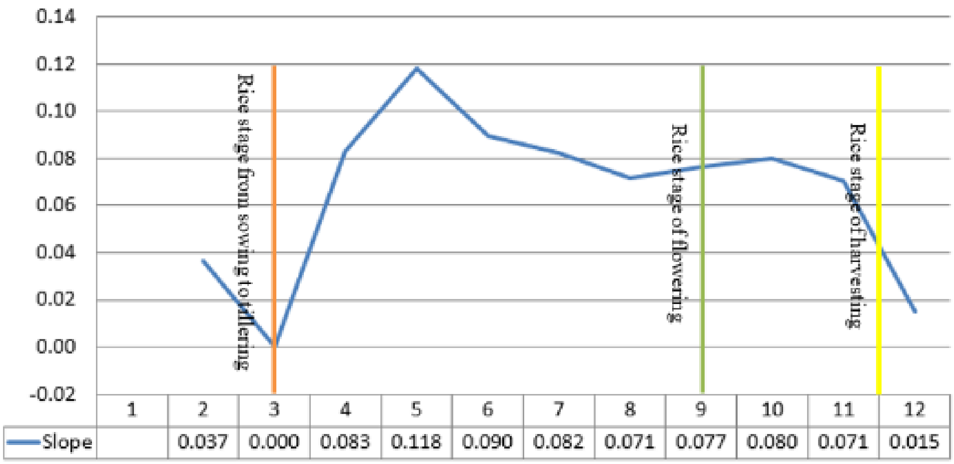


Fig. 16. Diagram of rice growth and development stage process interpreted from Sentinel-1 satellite images (average of 20 sample points)

Fig. 17. Rice stage from sowing to tillering

Fig. 18. Rice stage of flowering

Fig. 19. Rice stage of harvesting

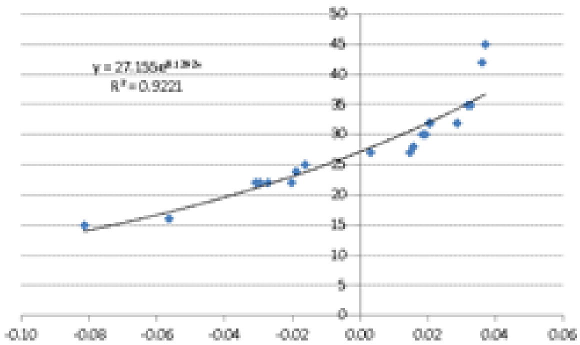


Fig. 20. Relations of the rice height measured with Slope value at the time of rice stage from sowing to tillering

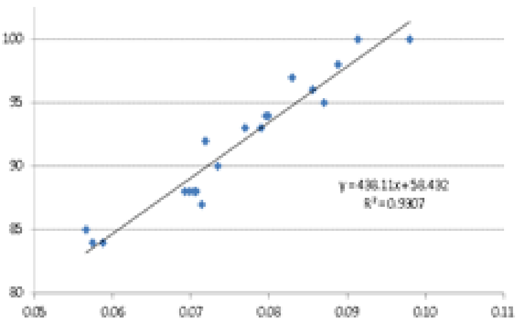


Fig. 21. Relations of the rice height measured with Slope value at the time the stage of flowering

4. Conclusion

This paper presents the methods and results of processing and interpreting Sentinel-1 and Sentinel-2 satellite images and the methods to evaluate the reliability of the interpretation results. We use the interpretation key table to interpret rice, vegetable, forest, and other plants on Sentinel-2 imagery and in the field to create a map of agricultural crops. This study also shows the relationship between the Sentinel-1 VH band and the growth of rice. From the image bands, we could calculate the slope of the line correlating between the VH backscattering value and the growth time of rice. Along with the local planting schedule, rice life cycle, and simple deduction, we could determine the rice growth stage at each time of image acquisition. We have programmed in Java to calculate the slope factor for the whole province of Ha Tinh and run it on computers with Intel Xeon processor, configuration E3-1505M v5 2.80GHz CPU, 32GB RAM memory. The time to output the result was less than 2 minutes. Therefore, a nationwide deployment will take about 2 hours. The result will be the input parameter for the irrigation management, monitoring and operating information system that is applied to Ha Tinh province for proper and effective irrigation.

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The World Maritime Oil Trade: One of the Main Causes of Oil Spills?

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Abstract

Oil is the main driver of the growth of modern economies due to its multifaceted use in transport, energy and manufacturing. The main objective of this work is to study the data on oil spills created by oil tankers over the past 50 years and to study the trend in oil trade and oil spill pollution in an attempt to analyze the state of environmental pollution during major oil disasters. The article also discusses the key factors in the occurrence of tanker oil spills and summarizes the strategy and directions for the development of the global marine transport industry to prevent future pollution of oil tankers. The analysis shows that the waters of the Atlantic ocean at the shores of Western Europe are most prone to the occurrence of major oil spill accidents.

It is assumed that with an increase in the volume of oil transportation, the number of accidents of oil tankers will also increase. But, as shown by statistical analysis, this is not so. Oil transport is becoming safer, and even in absolute numbers, the growth in traffic is accompanied by a decrease in the number of accidents accompanied by the release of oil and oil products. This is achieved mainly through logistics solutions and technical measures.

Keywords: oil trade, oil, maritime transport, leak, oil spills.

1. Введение

Нефть – природная маслянистая горючая жидкость со специфическим запахом, состоящая в основном из сложной смеси углеводородов различной молекулярной массы и некоторых других химических соединений (Мир-Бабаев, 2018).

Нефть как ключевой ресурс стратегического значения влияет на мировое экономическое здоровье и политическую стабильность. Добыча нефти, как в морском судоходстве, так и в других отраслях получила динамичное развитие, поскольку промышленно развитые страны во всем мире продолжают расширять использование богатых морских ресурсов. В настоящее время более 90 % мировых перевозок нефти осуществляется нефтяными танкерами (Гвоздиков, Захаров, 1996). В результате морская нефтетранспортная отрасль становится все более важной. Транспортировка нефти, принося различные экономические выгоды многим странам, также представляет серьезную угрозу. Аварии с разливом нефти угрожают жизни экипажей и здоровью людей и приносят огромные убытки транспортным предприятиям и грузовладельцам. Кроме того, разливы танкерной нефти серьезно затрудняют развитие морской экономики (рыболовство, туризм), наносят ущерб морским экосистемам со значительным ущербом морским экологическим ресурсам (Сугаипов и др., 2019). Несмотря на то, что технический прогресс существенно

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улучшил условия безопасности и возможности контроля и предотвращения со стороны властей, транспортировка нефти по-прежнему остается очень рискованным бизнесом как для людей, участвующих в ее добыче, так и для остального общества. Можно предположить, что рост спроса на нефть, а также увеличение объемов торговли нефтью, приводят к авариям с разливами нефти как к одному из основных факторов риска. Основной целью данной статьи является анализ представления о мировой морской торговле как о главном факторе влияния разливов нефти на наиболее серьезные аварии с разливами нефти, произошедшие за последние 50 лет во всем мире.

2. Обсуждение и результаты

Усиление экономического роста привело к увеличению спроса на минеральные масла во всем мире и стимулированию мировой экономики. Запасы нефти в основном сосредоточены на Ближнем Востоке и в бывшем Советском Союзе, в то время как потребление нефти в основном сосредоточено в Азиатско-Тихоокеанском регионе, Северной Америке и Европе.

Дисбаланс в распределении нефтяных ресурсов наряду с неравномерным спросом и предложением привело к непрерывному развитию морской торговли нефтью. Морская торговля (измеряемая в тонно-милях) в 2017 году составила 58,098 млрд. долл. тонн (Рисунок 1).

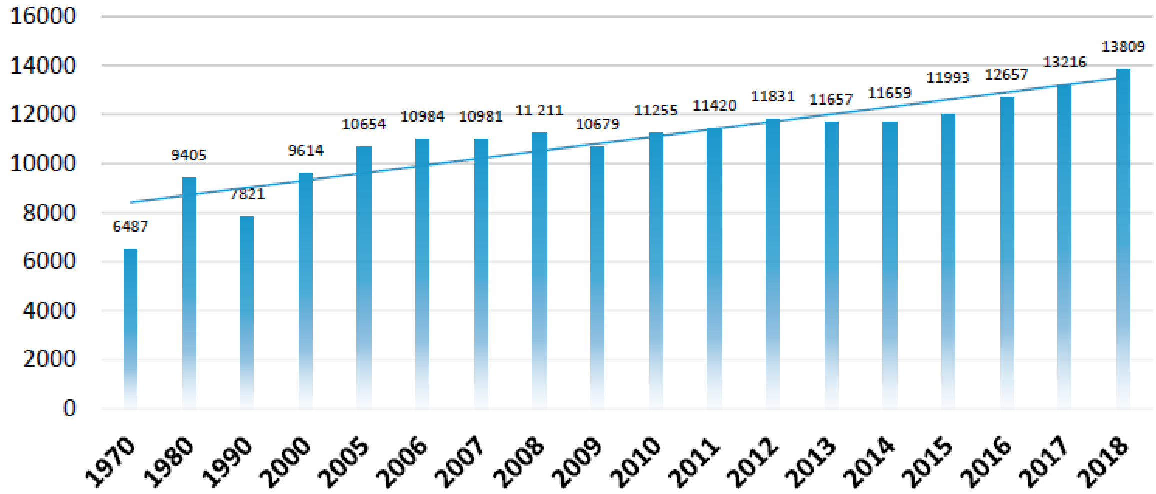

Рис. 1. Мировая морская торговля нефтью-миллиарды тонно-миль (1970-2018 гг.)
Источник: составлено авторами из ЮНКТАД

По данным «Global oil seatrade» за последние 50 лет, общий объем мировой торговли нефтью вырос. Однако до 1990-х годов она столкнулась с резкими колебаниями, причем максимальный объем торговли нефтью превысил 9000 долларов миллиард тонно-миль в год и минимальный показатель – 4,007 миллиарда тонно-миль (Lee et al., 2010).

После 1990-х годов ситуация стабилизировалась, и средний объем торговли нефтью составил около 10 000 тонно-миль в год. Большая часть роста была обусловлена поставками сырой нефти и угля, которые значительно улучшили судоходство. Тонно-мили танкерной торговли (включая сырую нефть и нефтепродукты) выросли на 4,4%. В 2017 году мировая торговля нефтью поддерживалась увеличением экспорта из Соединенных Штатов, ростом глобальной нефтеперерабатывающей деятельности и ростом цен на нефть. Экспорт, происходящий из Атлантического бассейна и предназначенный для Азии, где растут нефтеперерабатывающие мощности и потребности со стороны независимых нефтеперерабатывающих предприятий, способствовали увеличению спроса. Обзор крупнейших мировых компаний в нефтяном секторе (2017 г.) представлен на Рисунке 2.

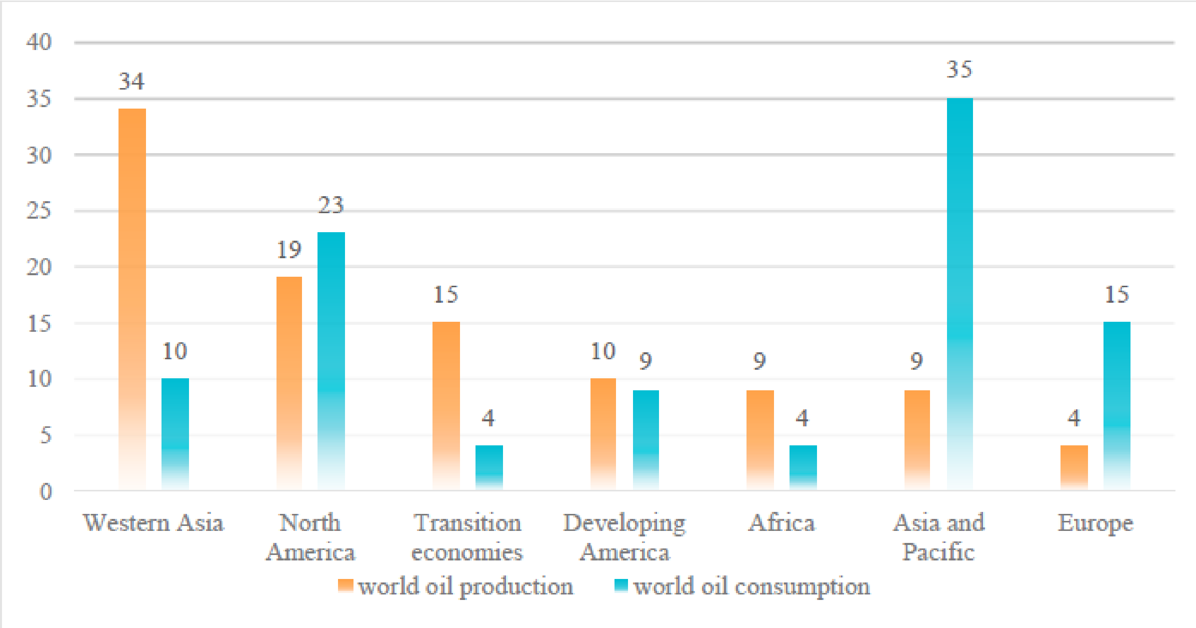

Рис. 2. Основные производители и потребители нефти – доля мирового рынка в процентах (2017 г.)
Источник: составлено авторами из ЮНКТАД

Китай, основными поставщиками которого являются Ангола, Исламская Республика Иран, Ирак, Оман, Саудовская Аравия, Венесуэла и Российская Федерация, безусловно, является ведущим импортером минерального сырья и сырой нефти. Китай как крупный экспортер нефтепродуктов удвоил объемы своего экспорта в период с 2013 по 2016 год. Кроме того, экспорт из Китая увеличился на 6,3 % в 2017 году, что обусловлено продолжающимся переизбытком нефтепродуктов в этой стране (Конопляник, 2016).

Обзор аварий при разливах нефти на море

Большая часть (около 90 %) мировых перемещений нефти осуществляется морем (Гвоздиков, Захаров, 1996). Морские организации и ведомства уделяют повышенное внимание транспортировке нефти по морю. Этот шаг обеспечивает значительное сокращение числа аварий с разливами нефти до минимально допустимого уровня (всего шесть в 2017 году). Несмотря на то, что технический прогресс значительно улучшил условия безопасности, транспортировка нефти по-прежнему остается весьма рискованным видом деятельности. Разливы нефти с танкеров составляют около 13% всего нефтяного загрязнения океанов по всему миру. Утечка с танкеров не только угрожает здоровью и жизни членов экипажа, но и представляет собой огромную экологическую потерю и серьезный ущерб окружающей среде и экосистемам (Гвоздиков, Захаров, 1996). Как только нефть утекает в море, она распространяется и дрейфует вместе с океанскими течениями и ветром, загрязняя пляжи, а также создает ущерб окружающей среде, особенно прибрежным туристическим районам с фатальным воздействием на морские экосистемы. Мировая транспортировка нефти по морю и обработка разливов нефти претерпели огромные изменения с тех пор, как супертанкер «Torrey Canyon» затонул в британских водах в 1967 году. Эта крупная авария с разливом нефти считалась одной из самых серьезных в мире. Супертанкер «Torrey Canyon», один из первых супертанкеров, сел на мель на рифе у юго-западного побережья Соединенного Королевства. Разлив составил примерно 119 328 тонн сырой нефти. Однако из-за отсутствия технических и компенсационных мер для борьбы с инцидентами разлива нефти в 1967 году, авария привела к значительному экологическому и экономическому ущербу как для Великобритании, так и для Франции. Эта авария с разливом привела к серьезным изменениям в реагировании на разливы нефти. За последние 50 лет, в связи с повышением внимания к аварийным разливам нефти со стороны морских агентств по всему миру, а также непрерывным развитием технологий танкерного транспорта общее число инцидентов с разливами нефти сократилось (Ликвидация…).

В 1990-е годы с шестью огромными авариями в океан выплеснулось 702 000 тонн нефти. Второй по величине разлив нефти в истории произошел в 1991 году, когда нефтяной танкер «ABT Summer», полностью загруженный сырой нефтью, необъяснимо взорвался и позже затонул у берегов Анголы. Погибли пять членов экипажа, четверо из которых числятся пропавшими без вести. Из-за потери 260 000 тонн нефти образовалось пятно длиной 32 километра и шириной 7 километров. Попытки найти место крушения после инцидента оказались безуспешными (Ликвидация…).

В том же году произошла еще одна крупная нефтяная авария, когда очень крупный нефтеналивной перевозчик "Хейвен", перевозивший на борту 144 000 тонн тяжелой сырой нефти, взорвался из-за электрической искры во время очистки цистерн. В результате аварии погибли шесть членов экипажа. В результате взрывов судно распалось на три части, основная часть судна затонула примерно в 2,8 км от берега после дальнейших взрывов. Данные показывают, что большинство аварий с разливом нефти произошло до 2000 года – только 3 значительных инцидента произошли после 2000 года (2000–2018 годы). Самый серьезный инцидент с разливом нефти 2000-х годов произошел в 2002 году. Нефтяной танкер "Престиж" затонул у берегов Галисии, перевозя груз в 77 тысяч тонн тяжелой бункерной нефти. Разлив загрязнил тысячи километров испанского, французского и португальского побережий, а с пляжей были извлечены промасленные морские птицы (Ликвидация…).

Любопытно, что в ходе этой катастрофы с разливом нефти, по решению испанских властей поврежденное судно отбуксировали в более глубокие морские воды. Этот шаг был описан как преступное деяние и представляет собой причину большого затронутого района.

Еще одна крупная нефтяная катастрофа с продолжающимися экологическими и экономическими последствиями произошла в 2007 году. Буксируемая крановая баржа столкнулась со стоящим на якоре нефтеналивным судном «Hebei Spirit», перевозившим 209 000 тонн четырех различных видов сырой нефти. Баржа свободно плавала после того, как трос, соединявший ее с буксиром, оборвался, пробив три грузовых танка по левому борту. Хотя сообщений о жертвах не поступало, столкновение привело к утечке 11 000 тонн нефти (Ликвидация…).

В 2010-е годы общий объем разливов нефти значительно снижается. О нисходящей тенденции свидетельствует прогресс, достигнутый в области предупреждения и ликвидации крупных аварий при разливах нефти. Однако несчастные случаи до сих пор происходят.

Например, авария «Санчи» в 2018 году нанесла огромные потери, в том числе со смертельным исходом и значительным ущербом морским экосистемам. Нефтяной танкер «Санчи» с полным грузом природного газа и конденсата в 136 000 тонн столкнулся с грузовым судном примерно в 300 километрах от Шанхая. «Санчи» загорелся вскоре после столкновения, после того как горел и дрейфовал больше недели, он наконец затонул. Ни один из его 32 членов экипажа не выжил. Вновь было привлечено внимание мирового морского сектора, и было настоятельно рекомендовано заняться ликвидацией разливов нефти (Ликвидация…).

Исходя из полученных данных, видно, что 19 из 20 крупнейших разливов нефти произошли до 2000 года. «Санчи», последнее дополнение к топ-20 значительных аварий нефтяных судов является единственным доминирующим разливом, и это привело к относительно низкому воздействию на окружающую среду по сравнению с некоторыми перечисленными авариями нефтяных разливов.

Проведенный анализ показывает, что воды Атлантического океана у берегов Западной Европы, которые имеют маршруты с интенсивным судоходством и сложную гидрологическую картину, более подвержены возникновению значительных аварийных разливов нефти, чем другие воды. Таким образом, морские нефтяные маршруты наиболее плотные в водах к западу от Европы (Рисунок 3 – морские нефтяные маршруты).

Существует однозначная зависимость между количеством перевозимого (экспортируемого) нефтяного груза (сырой нефти) и количеством разлившейся нефти.

Рис. 3. Плотность глобальных судоходных маршрутов

Разливы нефти против морской торговли нефтью

Морская торговля сырой нефтью играет значительную роль в мировой морской торговле. Танкерные перевозки содержат сырую нефть (80 %) и нефтепродукты (20 %). Несмотря на падение объемов перевозок в начале 1980-х годов во время мирового экономического кризиса, с 1990-х годов морская торговля нефтью стабилизировалась (Вылкован и др., 2000). Хотя увеличение объема транспортировки нефти, казалось бы, должна была повлечь за собой увеличение частоты разливов, эта тенденция изменилась в течение всего последнего периода.

Для сравнения: морская торговля нефтью на море в 1990 году составила 7821 миллиард тонно-километров с одиннадцатью авариями с утечкой в море более 700 тонн и 55 инцидентами с утечкой до 700 тонн нефти и нефтепродуктов. В 2017 году объем морской торговли нефтью возрос до 13 216 тонно-километров, причем наблюдалась одна авария с утечкой свыше 700 тонн, а три – до 700 тонн (Артюшкин, 2019). Сравнение тенденций торговли нефтью и загрязнения нефтью показано на Рисунке 4. Из него видно, что объем торговли нефтью неуклонно растет, но объем разливов снижается. С повышением осведомленности мировой общественности об аварийности танкерного судоходства во всем мире, одновременно ужесточились требования по безопасности и техническому освидетельствованию судов (особенно нефтяных танкеров). Все это и привело к сокращению числа аварий с разливами нефти на море. Несмотря на позитивные сдвиги в области борьбы с разливами нефти, мировые инциденты с нефтяными танкерами по-прежнему происходят с завидным постоянством.

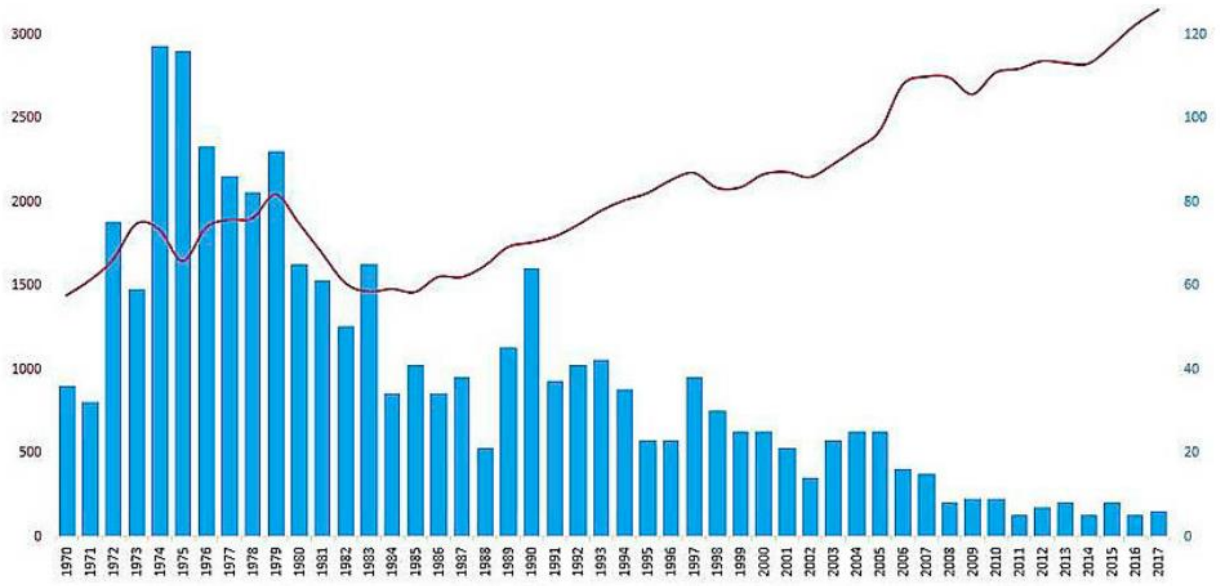

Рис. 4. Снижение количества разливов нефти по сравнению с ростом объема отгруженной нефти (млн метрических тонн)

3. Заключение

Морской транспорт относится к виду транспорта, который обеспечивает межконтинентальные перевозки пассажиров и грузов. Объемы торговли нефтью и ее перевозок по морю за последние несколько лет достигли значительного роста. С другой стороны, хотя морские перевозки и приносят огромные экономические выгоды многим странам, они также несут в себе огромные угрозы с негативным воздействием на здоровье, жизнь, имущество и окружающую среду. Даже не смотря на технический прогресс, транспортировка нефти по-прежнему остается крайне рискованным видом деятельности. Утечка нефти с танкеров сокращается, несмотря на общее увеличение объема торговли нефтью.

В статье представлен обзор наиболее крупных аварий с разливами нефти, произошедших на море за последние полвека. Анализ показывает, что воды Атлантического океана у берегов Западной Европы наиболее подвержены возникновению крупных аварий с разливом нефти. Поэтому имеется необходимость принятия разумного решения о регулировании добычи нефти, чтобы оптимизировать пути перевозок. Этот шаг обеспечивает снижение риска аварий при разливе до более низкого уровня, тем самым снижая угрозу здоровья, жизни, имущества и окружающей среды.

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Мировая морская торговля нефтью: одна из главных причин разливов нефти?

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Аннотация. Нефть является главным драйвером роста современных экономик благодаря ее многогранному использованию в транспорте, энергетике и обрабатывающей промышленности. Основной целью данной работы является изучение данных о разливах нефти, создаваемых нефтяными танкерами за последние 50 лет и изучение тенденции в торговле нефтью и загрязнении разливов нефти, в попытке проанализировать состояние загрязнения окружающей среды при крупных нефтяных катастрофах. В статье также рассматриваются ключевые факторы возникновения разливов танкерной нефти и

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подводятся итоги стратегии и направления развития мировой морской транспортной отрасли для предотвращения загрязнения нефтяных танкеров в будущем. Анализ показывает, что воды Атлантического океана у берегов Западной Европы наиболее подвержены возникновению крупных аварий с разливом нефти.

Предполагается, что с увеличением объемом перевозок нефти будет расти и количество катастроф нефтяных танкеров. Но, как показал статистический анализ, это не так. Нефтяной транспорт становится все более безопасным, и даже в абсолютном количестве рост объема перевозок сопровождается снижением количества несчастных случаев, сопровождаемых выбросом нефти и нефтепродуктов. Это достигается в основном за счет логистических решений и технических мероприятий.

Ключевые слова: торговля нефтью, нефть, морской транспорт, утечка, разливы нефти.