Geo-Ecological Basis for the Prospect of Using Agricultural Territory of Dong Nai Province, Vietnam

N T Hung1, K I Ivanovna2, M G Mengesha3
1Vietnamese National University of Forestry, Ha Noi, 1000, Viet Nam
2Voronezh State University, Voronezh, 394018, Russia
3Eritrea Institute Of Technology, College Of Science, Eritrea

E-mail: Thanhhungln02@gmail.com

Abstract. Geo-ecological assessments are widely used in the practice of modern environmental management. Dong Nai has favorable geographical features for developing high quality agriculture. The analyzed data indicated that the northeast region has prospects for agricultural development with food crops and fruit trees. The south and southwest areas are suitable for industrial-urban development combined with the development of perennial industrial crops. Organic agriculture will be the main trend in agricultural production of Dong Nai province, in order to improve the efficiency of agriculture and maintain the ecological environmental quality.

1. Introduction
Environmental pollution of heavy metals has become alarming worldwide. Along with industrial activities, mining, and transport, the abuse of fertilizers, chemicals and agricultural machinery is the cause of environmental pollution. [Fernandes and Henriques, 1991 ; Claire et al. 1991]. The accumulation of toxic substances in agricultural products will be a direct cause of harm to human and animal health [Marschner, 1995, Kupper et al. 2002; Pandey et al. 2002]. The demand for food always increases with the growth of the world population, but the cultivated area is limited. Therefore, humans are always looking for ways to improve crop yields. The most common and effective way to improve crop yield is to use chemical fertilizers and pesticides [Ali et al., 2017; Buccolieri A et al. 2010]. However, overuse of fertilizers and pesticides has resulted in serious pollution of the soil and an increase in the accumulation of heavy metals and toxic substances in agricultural products [Huang et al. 2008 , 2009; Alexakis et al. 2015; De Temmerman et al., 2003]. Therefore, to protect the safety of human health, a series of standards for clean food was developed. In particular, in developed countries, these standards are even more stringent. This shows that, in order to survive and develop, the agricultural sector must develop in the direction associated with organic production, minimize or eliminate the use of chemical fertilizers and plant protection drugs.

Currently, the main area of practical economic activity in Vietnam is agriculture. This is due to the very favorable natural conditions of the region. Currently the proportion of agriculture accounts for about 70% of Vietnam's economy. In particular, rice is one of the main agricultural crops [N. X. Cuong, 2019].
The annual rice output produced in Vietnam ranges from 40-50 million tons, with the rice cultivation area of about 7.5 million hectares [N. X. Cuong, 2019]. Vietnam is one of the two largest rice exporters in the world. Vietnam's and Thailand's rice exports account for about 47% of the total rice export in the world [N. X. Cuong, 2019]. Despite having the same geographical characteristics and located in the tropical monsoon climate region, however, export prices for Vietnamese agricultural products are always much lower than in Thailand [L. T.H. Xuan et al. 2019]. On the other hand, Vietnam has difficulty in exporting agricultural products to markets that require high standards, such as Europe or the United States, because most agricultural products (fruits, vegetables, rice, beans, coffee, peppers, etc.) have pesticide or heavy metal residues in excess of allowed levels. Most of Vietnam's agricultural products are exported to China, leading to the dependence of Vietnam's agriculture on China. This causes instability of agricultural development and reduces economic efficiency in agricultural production. In 2017, Vietnam developed the VIETGAP (Vietnam Good Agricultural Practice) set of standards to gradually increase the value of agricultural products. Evaluation results show that over 80% of Vietnamese agricultural products have not yet reached VIETGAP standards. The main reason for this situation is the excessive use of fertilizers and pesticides in agriculture. On the other hand, environmental pollution in agricultural production areas (soil, water and air pollution), in particular, heavy metal pollution is also the cause of increased accumulation of toxic substances and reduce crop productivity.

Therefore, in order to develop high-quality agricultural areas, first of all, it is necessary to select areas with good environment, clean (soil, water and air), then apply advanced production methods in accordance with VIETGAP standards to improve the quality of agricultural products. Dong Nai is an industrial province with a high risk of environmental pollution, but 75% of its natural territory is reserved for agricultural production. Thus, the identification of zones of clean agricultural development with a certain orientation of crops will be the key to improving the quality and economic efficiency of the agricultural sector. In this regard, we have built a scheme of priority development directions on the basis of maps for assessing the favorable conditions of soils for agricultural use. An integrated map made using overlay operations has become the basis of proposals for the development of the province.

2. Materials and methods

Air, soil and water pollution are three factors that directly affect agricultural crops. To assess soil, water and air pollution in Dong Nai province, Vietnam 100 soil, 20 air and 120 water samples were collected (80 surface and 40 ground water samples). Due to the geological characteristics of the region, it is rich in zinc, lead, copper, chromium, arsenic (metalloid) and cadmium. Therefore, the concentrations of these metals in the samples were analyzed. The integrated pollution map of each environment is determined based on the NIPI integrated evaluation model (Nemerow integrated pollution index). These three maps will then be stacked to form a common pollution map. This map revealed the general environmental pollution level caused by metals.

The second task is to determine the extent to which toxic metals affect plants. Of the above metals, lead, cadmium and As are considered the most toxic. However, the results revealed that arsenic concentration in soil, water and air is very low, the remaining metals, most of them have concentrations lower than the permitted limit. Therefore, to determine toxicity of metals, rice seed sowing had been conducted on the soil that has been contaminated by lead and cadmium only with different concentrations (0.01; 0.1; 1.0; 10; 30 and 100 mg/kg). Measurements of tree height, number of branches, root length and metal concentrations accumulated in rice plant parts (roots, stems, leaves and seeds) were measured and analyzed. From the results of the analysis, the threshold concentrations of Pb and Cd affecting rice has been determined, and combined with the integrated pollution map to form an agricultural development map.

NIPI are calculated according to formula [Yang et al. 2011].
\[ NIPI = \sqrt{\frac{PI_{\text{max}}^2 + PI_{\text{ave}}^2}{2}} \]  

where \( PI_{\text{max}} \) is the maximum PI value of each heavy metal 
and \( PI_{\text{ave}} \) is the mean PI value of each heavy metal 

\( PI = C_i / S_i \) pollution index 

\( C_i \) is the measured concentration of each metal 
\( S_i \) is the permissible concentration limit of each metal 

The NIPI is classified as no pollution (NIPI ≤ 0.7), warning line of pollution (0.7 < NIPI ≤ 1), low level of pollution (1 < NIPI ≤ 2), moderate level of pollution (2 < NIPI ≤ 3) and high level of pollution (NIPI > 3) (Yang et al., 2011).

3. Results

The analyzed results of the concentrations of metals in the soil, water and air environments are shown in Table 1. It can be observed that the average concentration of all metals in the air in the dry season is approximately 1.2–2 times higher than in the rainy season. The data showed that lead, copper and zinc were three metals that have higher concentration than others. The content of Pb, As and Cd is 1-3 times higher than the permissible level. Concentrations of Cu, Cr and Zn are below the acceptable threshold. The result showed that air pollution in the studied area is mainly associated with three metals - Pb, As and Cd.

Table 1. The concentration of metals in the air.

| Metal | Dry season (µ/m³) | Dry season (µ/m³) | S_i (µ/m³) |
|-------|------------------|------------------|------------|
|       | Max   | Min   | Ave  | SD    | Max | Min | Ave | SD |
| Zn    | 1,88  | 0,01  | 0,98 | 0,66  | 1,77 | 0,01 | 0,84 | 0,63 |
| Cu    | 1,22  | 0,00  | 0,33 | 0,36  | 0,53 | 0,00 | 0,16 | 0,15 |
| Cr    | 1,08  | 0,02  | 0,55 | 0,31  | 1,13 | 0,01 | 0,41 | 0,29 |
| As    | 0,09  | -     | 0,04 | 0,03  | 0,07 | 0,00 | 0,02 | 0,02 |
| Pb    | 2,36  | 0,00  | 1,23 | 0,84  | 2,09 | 0,00 | 0,92 | 0,69 |
| Cd    | 0,52  | -     | 0,06 | 0,11  | 0,70 | -   | 0,06 | 0,15 |

The results of the analyzed groundwater samples are given in table 2. According to the results of the analyzes, it can be argued that the concentration of metals, including As, Cd, Cr, Cu and Zn, was many times lower than the permissible standard values. In three of 40 samples, lead concentrations exceeded permissible levels by 1.2 times. These points are located in Bien Hoa (near the Dong Nai battery factory) and the Long Thanh Industrial Zone. The difference in the concentration of metals in groundwater in the dry and rainy seasons was negligible.

Table 2. The results of the analysis of the concentration of heavy metals in groundwater.

| Metal | C_i (mg/l) | Average C_i (mg/l) | S_i (mg/l) | PI |
|-------|------------|--------------------|------------|----|
|       | Dry season (Min-Max) | Rain season (Min-Max) | Dry season | Rain season (Min-Max) | Rain season (Min-Max) |
| As    | 0,001–0,007 | 0,001–0,0039 | 0,0012 | 0,0011 | 0,05 | 0,02–0,14 | 0,02–0,078 |
Table 3 shows surface water pollution — the concentration of As, Cu, Zn in surface waters is rather low. In some places, the concentration of metals Cd, Cr and Pb exceeded the permissible level (Cr above the Si is 1.92 times in the dry season; Cd is 2.76 times in the dry season and 1.87 times in the rainy season; Pb is 4.6 times in the dry season and 5.8 times in the rainy season). The most polluted areas are river sections running through industrial and urban areas. This showed that domestic wastewater and wastewater from factories were the causes of this pollution. This water can pollute the southwestern agricultural land area of the province.

Table 3. Concentrations of metals in surface waters.

| Metal | C<sub>i</sub> (mg/l) | Average C<sub>i</sub> (mg/l) | S<sub>i</sub> (mg/l) | PI |
|-------|-----------------|----------------|----------------|-----|
|       | Dry season (Min-Max) | Rain season (Min-Max) | Dry season | Rain season | Dry season (Min-Max) | Rain season (Min-Max) |
| As    | 0.001–0.0033  | 0.001–0.003  | 0.0011  | 0.0012  | 0.05  | 0.02–0.066 | 0.02–0.06 |
| Cd    | 0.0007–0.0083 | 0.0007–0.0056 | 0.0025  | 0.0024  | 0.003 | 0.238–2.767 | 0.238–1.867 |
| Cr    | 0.001–0.096  | 0.001–0.05  | 0.0153  | 0.0156  | 0.05  | 0.02–1.92  | 0.02–1.0  |
| Cu    | 0.024–0.5184 | 0.024–0.5184 | 0.1709  | 0.1728  | 1.00  | 0.024–0.518 | 0.024–0.518 |
| Pb    | 0.001–0.0069 | 0.0009–0.0087 | 0.0013  | 0.0014  | 0.0015 | 0.667–4.60 | 0.6–5.8 |
| Zn    | 0.05–1.090  | 0.05–0.29  | 0.0669  | 0.0581  | 5.00  | 0.016–0.218 | 0.01–0.058 |

The results of the analysis of metal concentrations in the soil are shown in table 4. The average concentration of metals indicated that, the soil in the study area is rich in copper, zinc, chromium and lead. The maximum concentration of metals is very high (Zn – 1054 mg/kg; Cr – 302 mg/kg, Pb – 150 mg/kg, Cu – 111 mg / kg, As – 29.5 mg/kg, Cd – 12.1 mg/kg). The standard deviation is quite high. This fact indicated that there is a big difference in the concentration of metals in different areas.

Table 4. The concentration of metals in the soil, (mg/kg).

| Metal | As | Cr | Pb | Cd | Cu | Zn |
|-------|----|----|----|----|----|----|
| Average | 5.04 | 87.40 | 13.76 | 0.28 | 32.77 | 88.03 |
| Standard deviation | 5.53 | 74.18 | 20.25 | 1.46 | 29.50 | 130.26 |
| Min    | 0.22 | 3.93 | 1.85 | 0.02 | 0.07 | 1.85 |
| Max    | 29.50 | 302.00 | 150.00 | 12.10 | 111.00 | 1054.00 |
| Si     | 15  | 150 | 70  | 1.5 | 100 | 200 |

An integrated geo-ecological map reflecting the distribution of environmental pollution, based on the multiplication of water, soil and air pollution maps (Fig. 1-4), showed that in most regions in the north and east, the level of metal pollution is insignificant (NIPI <1). In western and southern regions, low levels of
heavy metal pollution was observed. Higher pollution was detected in Vinh Kyu zone waste treatment area and a small area in the south, not far from Long Thanh Industrial Park. Waste treatment area has the highest metal pollution. This area receives a significant amount of waste from Dong Nai Province. Pollution levels in central and southwestern areas are higher than in northern and eastern areas. Some metals, such as Pb, Zn, and Cd have been detected at concentrations several times higher than the allowable concentration in water, soil, and air in the Long Thanh Industrial Park, Vinh Kyu Waste Treatment Area, and Dong Nai Battery Plant Area.

The results of the study on the effect of heavy metals on rice, the author presented in the papers published in Russian Agricultural Sciences and Bulletin of the Voronezh State University (Nguyen Thanh Hung et al. 2018; N. T. Hung et al. 2019). Threshold concentrations of contamination of the studied soils by lead and cadmium were revealed, the excess of which fixes the development of negative trends in agricultural growth indicators. For lead, the gradation is as follows: very favorable (with a metal content of \( \leq 10 \text{ mg/kg} \)); favorable (10-30 mg/kg); adverse (> 30 mg/kg). For cadmium: very favorable (\( \leq 0.1 \text{ mg/l} \)); favorable (from 0.1 to 1.0 mg/kg); adverse (> 1.0 mg/kg). An appropriate zoning map for rice cultivation has been developed based on the integrated pollution map stratification with lead and cadmium concentration thresholds. The results showed that 5 territorial groups were formed for development in different directions (Figure 5).

![Figure 1. Integrated map of soil pollution.](image1)

![Figure 2. Integrated map of air pollution.](image2)
Figure 3. Integrated map of water pollution.

Figure 4. Map of the integrated geoeconomic assessment of Dong Nai Province.

Figure 5. Diagram of directions for the further development of the territory of Dong Nai province.
Group 1. Very suitable for rice growth. These areas have very low metal concentrations in the soil, which is favorable for rice growth. In group 1, lowland areas with rich water resources can grow rice. Higher areas may be planted with fruit trees.

Group 2. Favorable for agricultural development. In order to implement food security policy, it is necessary to preserve and expand the land for food crops (rice, corn, beans). However, the economic efficiency of these crops is many times lower than that of growing fruit trees (such as durian, avocado, jackfruit, rambutan, mangosteen, grapefruit, etc.). Thus, in group 2, rice can be grown in low-lying areas, around rivers and streams, with abundant water sources, to achieve maximum efficiency. On higher plots and away from water sources, fruit trees and industrial crops such as rubber, pepper and coffee should be planted. This will help restructure the agricultural sector and increase the efficiency of agricultural production. It is observed that, group 2 has an environmental quality that meets the first requirement for the development of high-quality agricultural areas. The need to apply a production model and technology in accordance with the Vietgap standard, the quality of agricultural products will improve, thereby increasing the cost of agricultural products and expanding export markets, reducing dependence on the Chinese market.

In the Northwest region there is a large natural reserve with good environmental quality. Spa resorts can be built. The income from these activities can create a source of funding for the activities in the reserve and create livelihoods for the communities living around the reserve. The community in this area would enhance the spirit of environmental protection, minimize hunting and deforestation. This would ensure sustainable environmental safety.

Group 3. This is a territory with signs of pollution. This area should be recommended for industrial and agricultural activities with perennial industrial crops (such as rubber and eucalyptus). Agricultural development with perennial crops in group 3 is important. The main crops are rubber or eucalyptus. Eucalyptus trees are used for wood and rubber. These plants are large in size (can be higher than 10 m, wide canopy), grow quickly. When planted around industrial areas, they create a safe corridor to prevent the spread of pollutants to other areas. This would minimize the negative effects of metal pollution on human health. On the other hand, the income from these crops is quite high, which could ensure the economic efficiency of agriculture.

Groups 4 and 5. This is an area where immediate action is needed to control pollution. The Nkhon Trach industrial zone in the south and the Bien Hoa 1 industrial zone (in particular, the battery factory in Dong Nai) have a very high level of pollution with Cd, Pb and Zn. So the first solution is to relocate the Dong Nai battery factory from urban areas. After that, various measures can be used to detoxify the soil, such as the use of biological solutions, such as planting plants that can absorb heavy metals, such as poplar (Pteris vittata), grass Vetiver zizannioides, reed [Nguyen Diem et all, 2007; Tran Van Tua et al. (2010)]. Or maybe use of physical solution to remove contaminated soil. However, this solution requires huge funding. Therefore, although the biological solution lasts longer, it could be more economical and suitable in the current conditions of the region. The Nhon Trach industrial zone is located in the south, away from residential areas, but located in an area with a high density of canals that easily pollute water sources. In fact, the result showed that the river and stream around the area have a very high level of Cd pollution. Therefore, the solution is the need to create a large-scale waste management system in this area. On the other hand, an automatic monitoring system should be installed in the exhaust pipes of factories, so that timely control of waste quality can be discharged into the environment. This would limit the sources of pollution. Planting rubber or eucalyptus to create a buffer zone around the industrial zone will also help reduce the spread of pollution.

Waste treatment in Vinh Cuu is also a vital issue. It is considered the largest waste treatment area in Dong Nai province, handling most of the urban waste and hazardous waste from industrial parks and hospitals. The cause of severe environmental pollution is the waste treatment method. The main waste
processing methods are landfills (80%) and manual incineration (20%). Untreated garbage was buried and burned, resulting in the release of a very large amount of toxic wastes into the environment. Observations showed that air and soil are highly polluted in this area. Therefore, the proposed solution is to build a waste recycling plant with new technologies and minimize the activity of burying untreated waste. Some technologies may be referred to as: Swedish waste treatment technology (The amount of waste that must be disposed of in Sweden is only about 1%. The remaining 47% is recycled and 52% is incinerated to produce heat and electricity.) or using Austrian biotechnology waste recycling technology, or Japanese CFB incineration technology (This technology processes the waste by digging it into a layer of sand, then using the air stream during the kiln firing process, along with a number of other chemicals to destroy it. Trash inside the kiln would continuously be transported, and even the most stubborn materials would be destroyed in a very short time). Here are some of the technological solutions that have been applied and proven to be successful. Another cause of environmental pollution by metals is transport. About a third of the number of cars and motorcycles are outdated, with low environmental standards (made 10-20 years ago). Therefore, raising environmental standards to limit these types of vehicles is also an effective solution to reduce emissions of pollutants into the environment.

4. Discussion

Geo-ecological assessments are widely used in the practice of modern environmental management. Often they are limited to the assessment of individual environments, which is due to various systems of assessment criteria. Integral geo-ecological assessment involves a unified system of assessment criteria, which allows you to summarize information on a significant amount of data. In this work, the NIPI (Nemerow integrated pollution index) indicator is recommended as a criterion, accordingly the elementary geo-ecological assessment, systematized in the form of cartographic models, is given at the first stage; on the second, many map layers will be overlapped to form an integrated map. Its integrity is due to two positions: 1- application of a single methodology for constructing element-wise pollution maps, 2- summation of information based on environmental priority methods.

The classification results suitable for rice development showed that the northeast is the most appropriate. This area has good environmental quality, favorable for the development of clean agriculture. With low metal content in soil, water and air, even it has a positive effect on increasing crop yields (up 5-10%), while the difference in metal content accumulated in rice grains compared to rice grown on non-metal contaminated soil is negligible [N.T. Hung, 2019]. In this area rice and high value fruit trees can be grown (durian, jackfruit, mangosteen, grapefruit). Vietgap standards in agricultural production in this area should be applied not only to produce high quality agricultural products, but also a method to maintain the current environmental quality. From there, it is possible to develop sustainable agriculture.

Studies showed that soil contaminated with metals, the yield of plants decreases significantly and the accumulation of these metals in plants also increases in proportion to their level of pollution in land. Research results indicated that the southern and southwestern areas of Dong Nai province (group 3,4,5), show signs of pollution due to the presence of metals in soil, water and air. If rice is grown in this region, the negative effect from metal will likely reduce rice yields by 10-20%, and increase metal accumulation in rice grains by 3-5 times compared to rice cultivated in the northeast region [N.T. Hung, 2019]. According to Dong Nai’s economic development strategy, industry is always prioritized and expanded, so it is possible to plan the development of industrial areas in the south and southeast. This area not only has advantages in transport infrastructure (with adequate railway, road and waterway transportation systems to meet the requirements for transporting goods), but it also limits the spread of pollution to the east and north, due to its climate, hydrological and topographic features. In the dry season, pollutants can easily spread in the air because of the high temperature and no rain, but the main wind direction in the dry season is southwest wind, so the air pollutants would not spread to the northeast. The
rainy season has a northeast wind direction, but with heavy rainfall (1900-2400 ml/year, mostly falls in the 6 months of the rainy season, from May to November every year, so the level of air pollution in the rainy season reduced by about half compared to the dry season, which also limits the dispersion of pollutants). The terrain conditions are lower from north to south, so most of the currents originate from the north and flow southward. Therefore, the arrangement of industrial and transportation zones in the south and southwest will be minimized in the spread of pollution to other areas of Dong Nai province. When the density of industrial parks increases, likewise the sources of pollution would increase. However, this also creates an advantage of being able to build a centralized waste treatment plant with a large capacity that would facilitate the management and monitoring of waste into the environment. On the other hand, the development of agriculture with perennial crops (rubber, eucalyptus) in this area, not only enhances economic efficiency but also helps to reduce the spread of pollution.

5. Conclusion
The development direction of Dong Nai province is recommended as follows:

The northeast region has good environmental quality, favorable for the development of clean agriculture. This area should give priority to agricultural development (rice and fruit trees). The northwest of the region should develop tourism - resort. Southern and southwestern areas should develop urban industrial zones and transport and combined with agricultural development of perennial crops (rubber, eucalyptus).

Compliance these zoning guidelines will not only maximize the available geological and environmental advantages, but also help maintain and improve the quality of the environment. This would contribute to the improvement of quality and value of Vietnamese agricultural products in the world.

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