# An Integrated Decision Support System for Strategic Flood Mitigation Planning towards Sustainable Agricultural Waste Management at the Mekong Delta (IDSS-MEKONG)

(funded by UK Foreign Commonwealth & Development Office)

Project Lead: Dr Trung Hieu Tran

(Cranfield University, UK)

Version 2

## Executive Summary

**Background:** The Mekong Delta plays an important role in agricultural development of the ASEAN countries such as Vietnam, Laos, and Cambodia. The delta supports a population of about 18 million people by providing water for agriculture and a means of transportation. Although the delta's area is only 12.1% of Vietnam area, it contributes more than 90% of the quantity of Vietnam's exported rice. As a result, the annual quantity of rice straw in the Vietnamese Mekong Delta is approximated of 26.2 million tons (42% of Vietnam's rice straw), of which 20.9 million tons is burned directly on the fields, which led to a contribution of approximately 17.95 million tons of CO2, 485.58 thousand tons of CO and 10.38 thousand tons of NOx into the atmosphere. The study shows that most of farmers tends to continue burning rice straw as a habit in the coming years. Therefore, there is an urgent need of innovative solution approaches for dealing with the challenge at the Mekong Delta.

**Aim and objectives:** This project aims to develop and implement a sustainable agricultural waste management model at the Mekong Delta (covering the region of Vietnam, Laos, and Cambodia) to stop burning the agricultural waste at fields and utilise the waste for bio-organic fertilizer, mushroom and biomass energy production. In addition, a strategic flood mitigation planning model is developed and integrated to mitigate the flood impact on agricultural waste management model (or climate resilience).

**Methodology:** To achieve the project's aim and objectives, a data-driven solution approach is developed based on Operational Research techniques, a branch of Mathematical Science. Specifically, we formulate two mixed-integer linear programming models for planning flood impact mitigation strategies, and for sustainable agricultural waste collection and transport network design at the Mekong Delta. The first model will be applied for the road and river infrastructure systems of the Mekong Delta to enhance the resilience of transport networks under climate change towards a sustainable agricultural waste management. The second model will be applied for designing an efficient agricultural waste collection and transport network under impact of flooding at the Mekong Delta. It can determine the most reliable storage and facility locations for collecting agricultural waste from fields to storages and from storages to facilities at the Mekong Delta. A case study at An Giang province, the Vietnam Mekong Delta will be used to evaluate the performance of these models.

**Results:** This project identified the practical needs and challenges of achieving sustainable agricultural waste management at the Mekong Delta via the online survey and interviews. The optimisation models developed can mitigate the impacts of flooding on the agricultural waste collection and transport network which led to achieving a sustainable agricultural waste management model at the Mekong Delta (i.e., stopping burning agricultural waste at the fields

after harvesting, and utilising the waste for bio-organic fertilizer, mushroom and biomass energy production). The case study demonstrated that stopping burning agricultural waste at the Mekong Delta could improve air quality, welfare and promote the bio-organic fertilizer, mushroom and biomass energy (from the waste) production development at the region. Specifically, this project developed a novel mathematical programming model and algorithm for the reliable storage-and-facility location problem which can build a sustainable agricultural waste collection and transport network under impact of flooding at An Giang province. The model proposed using 11 temporary storages with large capacity, located at 11 districts of An Giang province (i.e., Long Xuyên, Châu Đốc, An Phú, Tân Châu, Phú Tân, Châu Phú, Tịnh Biên, Tri Tôn, Chợ Mới, Châu Thành, Thoại Sơn), to collect and store agricultural waste (i.e., rice straw) from the fields before delivering to the corresponding facilities. As compared with the current solution, the novel solution reduced 30% disruption risk for the sustainable agricultural waste management at the province. Finally, this project engaged wider stakeholders from ASEAN countries to the challenges at the Mekong Delta via the workshops.

**Impact of the result to targeted beneficiaries in the study sites:** The success of this project will improve the health and welfare of farmers, street vendors, local citizens, drivers, workers, and employees at the bio-organic fertilizer production facilities who directly work in agricultural waste management in the Mekong Delta. Many female farmers, male drivers and female workers/employees will receive benefits from this project such as increasing the employment rate and the economic growth. Furthermore, the quality of air and water will be improved as burning agricultural waste is stopped. This project can affect the relations between people of different genders and people of the same gender by attracting male workers from cities to come back to work in facilities that produce bio-organic fertilizer, mushroom and biomass energy from agricultural waste. Although it does not make much role change, balance of household responsibilities is achievable. The male workers working at near-home facilities could share household responsibilities with female such as caring of children, elderly, etc. Reducing burden of household responsibilities on female can leverage gender inequalities in society and economy. Earnings and savings of female can be improved when they have more job opportunities at the bio-organic fertilizer, mushroom and biomass production facilities.

**Scalability of the results / innovation at ASEAN level:** Our robust optimisation models can be extended and adapted for other ASEAN countries (with the similar characteristics/conditions/policies) towards a sustainable agricultural waste management. In addition, the sustainable agricultural waste management model can enhance the supply chain development of mushroom, biomass energy, bio-organic fertilizer and products at ASEAN countries, leading to the impact mitigation of climate change on agriculture production and waste management at the region.

**Project Partners**

| Lead organisation: | Country | Member | Expertise | Role |
|---|---|---|---|---|
| Cranfield University (CU) | UK | Dr Tran Trung Hieu | Data Analytics, and Location Optimisation | Project management, and developing and solving strategic flood mitigation planning model |
| **Project partners:** | | | | |
| University of Bedfordshire (UoB) | UK | Dr Nguyen Thi Thu Ba | Vehicle Routing Network Optimisation | Developing agricultural waste collection and transport network, and solving the vehicle routing problem |
| University of Loraine (UoL) | France | Prof Le Thi Hoai An | Global Optimisation | Solving practical non-convex constraints in the models |
| **ASEAN partners:** | | | | |
| Vietnam National University of Agriculture (VNUA) | Vietnam | Dr Dinh Thi Hai Van | Climate Change and Adaptation, Sustainable Agricultural Development | Innovative alternatives for agricultural waste treatment<br><br>Piloting technology to produce organic fertilizers |
| Asian Management and Development Institute (AMDI) | Vietnam | Mrs Be Thi Hoang Yen | Social Science | Survey for economic, environmental, and social impact of climate change on the Vietnam Mekong Delta<br><br>Organise the final workshop |
| Institute of Meteorology, Hydrology and Climate Change (IMHEN) | Vietnam | Mr Phung Duc Chinh | Climate Change and Flood Simulation | Data collection (e.g., rainfall, road network, etc.)<br>Rainfall simulation<br>Flood map generation |
| National University of Laos (NUoL) | Laos | Dr Vatthanamixay Chansomphou | Environmental Science | Survey for economic, environmental, and social impact of climate change on the Laos Mekong Delta |
| Mekong River Commission Secretariat (MRCS) | Cambodia | Mr Hour Ix | Disaster Flood and Drought Management, Agriculture | Survey for economic, environmental, and social impact of climate change on the Cambodia Mekong Delta |

# Acknowledgement

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## Abbreviations

| | |
|---|---|
| LRP | Location-Routing Problem |
| LARP | Location-Assignment-Routing Problem |
| RSFLP | Reliable Storage-and-Facility Location Problem |
| MINLP | Mixed-Integer Non-Linear Problem |
| MILP | Mixed-Integer Linear Problem |
| SAWM | Sustainable Agricultural Watse Management |
| FMP | Flood Mitigation Problem |
| CU | Cranfield University |
| UoB | University of Bedfordshire |
| UoL | University of Loraine |
| AMDI | Asian Management and Development Institute |
| IMHEN | Institute of Meteorology, Hydrology and Climate Change |
| VNUA | Vietnam National University of Agriculture |
| NUoL | National University of Laos |
| MRCS | Mekong River Commission Secretariat |
| IDSS | Integrated Decision Support System |
| ASEAN | The Association of Southeast Asian Nations |
| WP | Work Package |
| RA | Research Activity |
| KD | Key Deliverable |
| DARD | An Giang Department of Agriculture and Rural Development |
| KB | Key Beneficiaries |

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## 1. Background

Some ASEAN countries' agricultural sectors have rapidly developed to become major contributions to the growth of national economy. Accompanying the development, however, agricultural waste management has posed a challenge for planners due to the lack of a sustainable waste management model. In 2021, for example, Vietnam' s agricultural export revenue achieved US$21.29 billion (Vietnam's agricultural export revenue, 2021). The consequence of the achievement is that the country needs to deal with the huge amount of agricultural waste, approximately 106 million tons including 63 million tons of rice straw. Burning the agricultural waste (rice straw) at fields after each harvesting season is the present solution at the country, which has increasingly caused air and water pollution in rural areas of the country.

The Mekong Delta plays an important role in agricultural development of the ASEAN countries such as Vietnam, Laos, Cambodia, etc. The delta supports a population of about 18 million people by providing water for agriculture and a means of transportation. Although the delta's area is only 12.1% of Vietnam area, it contributes more than 90% of the quantity of Vietnam's exported rice. As a result, the annual quantity of rice straw in the Vietnamese Mekong Delta is approximated of 26.2 million tons (42% of Vietnam's rice straw), of which 20.9 million tons is burned directly on the fields, which led to a contribution of approximately 17.95 million tons of CO2, 485.58 thousand tons of CO and 10.38 thousand tons of NOx into the atmosphere. Tran et al. (2023) shows that most of farmers tends to continue burning rice straw as a habit in the coming years. Therefore, there is an urgent need of innovative solution approaches for dealing with the challenge at the Mekong Delta.

This project will develop and implement a sustainable agricultural waste management model at the Mekong Delta (covering the region of Vietnam, Laos, and Cambodia) to stop burning the agricultural waste at fields. To mitigate the flood impact on agricultural waste management (or climate resilience), a strategic flood mitigation planning model is also developed and implemented. A decision support system integrated from these two models will help fully solve the above-mentioned challenge at the Mekong Delta, which is towards United Nation's Sustainable Development Goals (SDGs) such as SDG9 - Industry, Innovation, and Infrastructure, SDG11 – Sustainable Cities and Communities, SDG12 - Responsible Consumption and Production, SDG13 - Climate Action, and SDG17 – Partnerships for the Goals.

## 2. Literature Review

In logistics, facility location and vehicle routing are known as two of the most important optimisation problems. These problems are often studied separately. A study of interdependence between two optimisation problems was started in 1989 (Salhi & Rand, 1989). Since then, the continuous research of the integrated approach of these problems is done, known as LRP. A literature review of the LRP and its variants over the past few years has been done and reported in Mara et al. (2021). This study draws the state-of-the-art of LRP research and its applications.

The authors studied two main characteristics of LRPs such as:

- ***Problem scenario****:* data, planning period, objective, generalised customer, prize collecting, load splitting, backhaul, inventory decision, time window structure, vehicle usage, and open trip.
- ***Physical characteristics****:* echelon, location of facilities, routing, product or service, vehicle homogeneity, capacity consideration, inter-facility transport, and intra-route facilities.

The characteristics are related to strategic, tactical, and operational decisions in the LRPs, for example, problem scenario (i.e., strategic, and tactical decisions) and physical characteristics (i.e., strategic, and operational decisions). Based on the different characteristics, various modelling and solution approaches have been developed to adopt with the specific problems. The study pointed out that the knowledge gap between academic and practitioners in LRP has been gradually eliminated when the application of LRP model in real-life case studies has increased. Application areas of LRP case studies consist of agriculture, airline, automotive logistics, city logistics, defence and military, e-commerce, electric vehicles, emergency and disaster management, food distribution, healthcare logistics, oil and energy, postal delivery, railroad, telecommunication, underground logistics system, unmanned aerial vehicles, and waste management. This literature review concentrates in three streams: applications of LRP for waste management or agriculture, and related location-inventory-routing problem (LIRP).

### 2.1. Application of LRP for waste management

**In municipal solid waste management**, a mixed-integer programming model of the LRP is formulated to locate the facilities (e.g., transfer stations, treatment, recycling and disposal centres) from the site candidates and determine the routes and amounts of shipments among the selected facility locations to minimize the total cost of transportation and facility establishment (Hossein, Samsung, & Mojtaba, 2015). A simulated annealing algorithm is adapted to solve efficiently the large-sized instances for the integrated municipal solid waste LRP (Asefi, Lim, & Maghrebi, 2017). A hybridisation of variable neighbourhood search and simulated annealing for exploring the feasible solution space and overcoming the traps of local optimums is developed to improve the algorithm's performance (Asefi, Lim, Maghrebi, & Shahparvari, 2019).

**In obnoxious waste management** (i.e., wastes generated by dry cleaners, auto repair shops, exterminators, chemical manufacturers, and oil refineries), a multi-objective LRP model is developed to minimise the treatment and disposal facility undesirability, different related costs, and the risk associated with transportation of untreated materials (Nasrin, Mohsen, Masoumeh, Maryam, & Zanjirani, 2016). A memetic algorithm that uses a tabu search in the local search phase is developed to solve the multi-objective optimisation problem.

**In hazardous waste management** (i.e., medical and industrial wastes) in which energy recovery from waste and polluter pays principle are considered, a profit-oriented mixed-integer programming model is proposed to determine the locations and numbers of recycling, incineration, sterilization, interim storage and disposal centres, and plan the vehicle routes for transferring various types of hazardous waste and waste residues among these centres from the perspective of environmental protection (Aydemir-Karadag, 2018). Ghezavati & Morakabatchian (2015) developed a multi-objective location-routing model for solving a real case study of Petrochemical Special Economic Zone in Khuzestan, Iran. This model can determine the optimal locations of suitable treatment, recycling and disposal centres, and the optimal routes for transporting of different types of industrial wastes between the centres. Two objective functions are to minimize total costs of transportation and establishment of the centres and total transportation and site risks. In addition, they consider fuzzy customer satisfaction level for the waste collection system. Hu, Li, Zhang, Shang, & Zhang (2019) investigated the constraint of traffic restrictions in inter-city roads for hazardous material logistics, and proposed an adaptive weight genetic algorithm for solving the problem in which multiple paths between every possible origin-destination pair are allowed. A real-world case study was constructed to demonstrate the efficacy of the proposed model and solution method.

**In used oil management**, Zhao & Verter (2015) presented a bi-objective LRP model to minimize the total environmental risk and the total cost. They applied a modified weighted goal programming approach to deal with this problem. The model is applied in Chongqing of Southwest China. Renan, Koc, & Bektas (2016) studied a multi-period LRP for the collection of Olive Oil Mill Wastewater to the treatment facilities by using a fleet of vehicles. This study aims to reduce potential contamination impact on environment due to disposal of wastewater into soil or rivers. They proposed an adaptive large neighbourhood search metaheuristic for solving this problem and constructed a case study to evaluate the algorithm.

**Another application of LRP in waste management** can be encountered in glass recycling (Rahim & Sepil, 2014) in which a combination of maximal covering location problem and selective traveling salesman problem is studied to determine the location of bottle banks and the route of a collecting vehicle visiting a number of customers and the bottle banks. A nested heuristic procedure was proposed to solve the problem. Sheriff, Nachiappan, & Min (2014) studied a plastic recycling industry in Southern India to cope with the problem of picking up recyclable plastic bottles using private collecting agents, transferring those bottles to the initial collection points, and then transhipping and consolidating them at the centralized return centres for final shipments to the processing centres where these bottles were treated for recycling. The main contribution of this study includes the simultaneous consideration of location, allocation, and routing decisions. In addition, it first considers incentive payments, the quality level of products, and multiple types of products. Sakti, Yu, & Sopha (2018) applied the LRP to the design of a waste supply chain network in the Special Region of Yogyakarta, Indonesia. The model studied two types of fleets to determine depot locations, waste-based power plant locations, service allocations, and associated routes.

In addition, integration of inventory into LRP in waste management is considered in some research works. For example, Lerhlaly, Lebbar, Allaoui, Ouazar, & Afifi (2016) studied the optimisation of operating costs, risks and routing's $CO_2$ emissions in Hazmat supply chain. The study aims to determine the location of capacitated depots, the allocation of customers to depots, the quantities from these depots to customers per period, and the vehicle routes. An exact bi-objective model is developed for solving the small-and-medium-sized problem. The model is tested on a case study to demonstrate its industrial practicality. Zhalechian, Tavakkoli-Moghaddam, Zahiri, & Mohammadi (2016) studied environmental impacts of $CO_2$ emissions, fuel consumption, wasted energy, and social impacts of created job opportunities and economic development on a closed-loop location-routing-inventory supply chain network design under mixed uncertainty. A stochastic-possibilistic programming approach was applied to cope with the uncertainty and a hybrid meta-heuristic algorithm was developed to solve the problem efficiently. The applicability of model and algorithm was demonstrated in a real case study. Yuchi, He, Yang, & Wang (2016) introduced a new location-inventory-routing problem in forward and reverse logistic network design. The problem considers simultaneously decisions of distribution centres location, their inventory policies, and vehicle routes in serving customers such that minimisation of the total costs of manufacturing and re-manufacturing goods, building distribution centres, shipping, distributing, ordering and storage costs of goods. A nonlinear integer programming model was developed to formulate the problem. A new tabu search algorithm was proposed to solve the problem. Zhao & Ke (2017) studied impact of inventory risks on location and routing decisions in explosive waste management. An optimization model was developed to simultaneously minimize total cost and risk. The model locates the collection centres, manages the inventory level for each centre, determines the number of vehicles to be purchased, finding the optimal routes for transporting explosive wastes from generation nodes to collection centres, and from collection centres to recycling centres. A case study in Nanchuan of Southwest China was used to test and evaluate the performance of this model.

### 2.2. Application of LRP in agriculture

There are some recent applications of LRP in agriculture. For example, Chen, Qiu, & Hu (2018) investigated the LRP with full truckloads for low-carbon supply chain network design. A bi-objective optimisation model is developed to determine the number and locations of facilities and optimise the flows among different types of nodes and truck routes such that total cost and environmental effects are simultaneously minimised. A multi-objective hybrid approach based on the combination of genetic algorithm and tabu search, is proposed to solve this problem. They applied the model for the regional timber supply network design in Jiangle county, Fujian province, China. Akararungruangkul & Kaewman (2018) investigated the special case of the LRP in which fuel consumption depends on the distance of travel and the condition of the road. They customised the model for the rubber field industry in Nakorn Panom province, Thailand.

### 2.3. Other LIRP applications

Considering simultaneously three decision variables (location, inventory, and routing) has also been studied and applied in a range of fields. Ambrosino & Grazia Scutella (2005) was known as the first researchers that combined three decision variables of warehouse location, inventory management and route planning into distribution network design problem. Two kinds of mathematical programming formulations were proposed for the integrated network design, together with a proof of their correctness. Ahmadi-Javid & Seddighi (2012) built a ternary-integration MINLP model for the LIRP in a multi-source supply chain and developed a three-phase heuristic algorithm for solving efficiently the large-sized instances. Guerrero, Prodhon, Velasco, & Amaya (2013) introduced a 5-index mixed-integer linear programming (MILP) model for the LIRP over a discrete time planning horizon, and proposed a hybrid method, embedding an exact approach within a heuristic scheme, to solve the problem. Zhang, Qi, Miao, & Liu (2014) formulated a 4-index MILP model to address long-term replenishment strategies, in which a smart representation of inventory cost is used to reduce computational complexity. In addition, the authors proposed a hybrid metaheuristic algorithm consisting of initialization, intensification, and post-optimization to solve the large-sized instances. Ghorbani & Akbari Jokar (2016) investigated a multi-product multi-source LIRP with backlogging policy for the split-souring of products and developed a hybrid heuristic algorithm based on the simulated annealing and imperialist competitive algorithm to solve the problem. Hiassat, Diabat, & Rahwan (2017) developed a 3-index MILP model for the multi-period LIRP with perishable products and applied a genetic algorithm with a novel chromosome representation for finding good solutions within a reasonable computational time. Zheng, Yin, & Zhang (2019) studied the integrated LIRP model with the limited number of customers in a route and restrictions on service radius, reformulated it as a 4-index mixed-integer convex program with nonlinear objective function, and developed an exact algorithm based on Generalized Benders Decomposition method for solving the reformulated model. Wu, Zhou, Lin, Xie, & Jin (2021) built a multi-period multi-echelon LIRP model with time windows and fuel consumption in which the replenishment is considered and the stock-out situation is allowed. The authors proposed a two-stage hybrid metaheuristic algorithm for solving the problem, in which a customized genetic algorithm is used in the first stage, and a gradient descent algorithm is applied in the second stage for the inventory decision improvement in reducing the total cost. Recently, Shang, Zhang, Jia, & Almanaseer (2022) studied the LIRP model for a healthcare supply system with multiple products, multiple periods and multi-type delivery. In the model, some potential warehouses are selected as vendor managed inventory (VMI) warehouse locations, and products are delivered to VMI warehouses by bulk delivery to hospitals through direct shipping. The authors proposed a deterministic MILP model for the integrated LIRP, and a robust optimisation model (which is transformed into a tractable linear equivalent formulation) for solving the problem under uncertain demand. In addition, a new robust optimisation model was developed to consider the effect of COVID-19 pandemic on the demand and delivery time.

For environmental context, Ji, Ji, Ji, & Liu (2022) studied the sustainable combined location-inventory-routing problem (CLIRP) for a garment chain enterprise, in which the objective function is to minimise logistics costs and emission simultaneously. The authors proposed a two-stage solution method where a heuristic algorithm finds the initial solution, and a hybrid heuristic algorithm between tabu search and simulated annealing is applied to search for the global near-optimal solution. Lv & Sun (2022) developed a multi-objective mixed-integer programming (MIP) model for the CLIRP in auto parts supply logistics to minimise the total system cost and carbon emissions while concerning multi-period production demand. A robust optimisation model is proposed to deal with the problem under uncertain demand. Nasiri, Mousavi, & Nosrati-Abarghooee (2023) studied a green LIRP with simultaneous pick-up and delivery under disruption risks. The model is to minimise lost demands, and the network's total costs are considered budget constraints. A scenario-based approach is applied to deal with the demand uncertainty and risks caused by the centres' capacity disruptions.

Wang & Nie (2023) introduced a path-based LIRP model for a dynamic last-mile emergency supply distribution plan, including a local distribution centre, points of distribution, and demand points. In the model, both cost and equity are considered into the objective function to ensure that distribution of emergency supplies is cost-efficient and fair. The model outperforms different comparison models as applying for a case study of the flooded Red Hook neighbourhood in New York City during Hurricane Sandy.

### 2.4. Research question

Table 1 provides a summary of these recent works for LRP in waste management and agriculture, as well as related LIRP under a classification of real-world application, single/multi-objective function, type of decision variable, and solution method. We observe four types of decision variables in the LRP such as location, routing, assignment, and inventory.

Unlike the allocation of customers to depots/facilities via vehicle routes that is included in routing decisions, allocation (i.e., assignment) decisions which we consider in this paper are similar to the assignment of customers to facilities in a facility location problem (Tran, Scaparra, & OH́anley, 2017). From the literature review, therefore, Sheriff et al. (2014) is the most relevant work to our studying LARP.

However, their model specialises for the optimisation problem in the plastic recycling industry and is challenged to extend for dealing with other areas. The main difference between the LARP and the problem of Sheriff et al. (2014) is that Sheriff et al. (2014) studied the problem of picking up recyclable plastic bottles, transferring the bottles to the initial collection points (ICPs), and then transhipping and consolidating them at the centralized return centres (CRCs) for final shipments to the recycling centres. This problem thus combines the LRP with the balanced allocation problem in the closed-loop supply chain network. In other words, the authors consider simultaneously location decisions of ICPs and CRCs for allocation of pick-up points to ICPs, as well as allocation of ICPs to CRCs, and routing decisions at ICPs and

CRCs level. Again, the allocation decisions are to find optimal vehicle routes to collect and transport plastic bottles to ICPs, CRCs and the recycling centres.

Table 1: A summary of various LRP applications in agriculture and/or waste management.

| Reference | Application | Objective | Decision* | | | | Solution method |
|---|---|---|---|---|---|---|---|
| | | | L | R | A | I | |
| Rahim & Sepil (2014) | Glass recycling | Single | x | x | | | Nested heuristic algorithm |
| Sheriff et al. (2014) | Plastic recycling | Single | x | x | x | | MILP |
| Hossein et al. (2015) | Municipal solid waste | Single | x | x | | | MIP |
| Ghezavati & Morakabatchian (2015) | Hazardous waste | Multiple | x | x | | | Fuzzy service level constraint programming |
| Zhao & Verter (2015) | Used oil | Multiple | x | x | | | Modified weighted goal programming |
| Nasrin et al. (2016) | Obnoxious waste | Multiple | x | x | | | Combination of memetic algorithm and tabu search |
| Lerhlaly et al. (2016) | Drinking water distribution | Multiple | x | x | | x | Exact bi-objective model |
| Renan et al. (2016) | Olive oil mill wastewater | Single | x | x | | | Adaptive large neighbourhood search meta-heuristic |
| Zhalechian et al. (2016) | Closed-loop supply chain | Multiple | x | x | | x | Stochastic-possibilistic programming, meta-heuristic |
| Asefi et al. (2017) | Municipal solid waste | Single | x | x | | | Simulated annealing |

| Reference | Application | Objective | Decision* | | | | Solution method |
|---|---|---|---|---|---|---|---|
| | | | L | R | A | I | |
| Zhao & Ke (2017) | Explosive waste | Multiple | x | x | | x | TOPSIS method |
| Aydemir-Karadag (2018) | Hazardous waste | Single | x | x | | | Profit-oriented mixed-integer programming |
| Sakti et al. (2018) | Waste supply chain | Single | x | x | | | Mathematical model and greedy algorithm |
| Asefi et al. (2019) | Municipal solid waste | Single | x | x | | | Variable neighbourhood search, simulated annealing |
| Hu et al. (2019) | Hazardous material logistic | Single | x | x | | | Adaptive weight genetic algorithm |
| Yuchi, Wang, He, & Chen (2021) | Forward and reverse logistic | Single | x | x | | x | Tabu search |
| Akararungruangkul & Kaewman (2018) | Rubber field | Single | x | x | | | Modified differential evolution algorithm |
| Chen et al. (2018) | Timber supply chain | Multiple | x | x | | | Multi-objective hybrid approach |
| Shang et al. (2022) | Healthcare supply system | Single | x | x | | x | MILP, robust optimisation |
| Ji et al. (2022) | Garment chain enterprise | Single | x | x | | x | Tabu search and simulated annealing |
| Lv & Sun (2022) | Auto parts supply logistic | Multiple | x | x | | x | Robust optimisation |
| Nasiri et al. (2023) | Green logistic | Single | x | x | | x | Scenario-based approach |

| Reference | Application | Objective | Decision* L | R | A | I | Solution method |
|---|---|---|---|---|---|---|---|
| Wang & Nie (2023) | Emergency supply distribution | Single | x | x | | x | MILP |
| Tran et al. (2023) | Agricultural waste | Single | x | x | x | | MINLP, linearise model, PWFA |

*Note that L = Location, R = Routing, A = Assignment, and I = Inventory.

The LRP application for agricultural waste management has not been investigated fully. Hence, we developed a novel mathematical programming model and a natured-inspired algorithm to solve such large-scale instances within a reasonable computation time (Tran et al., 2023). The paper enhanced the LRP application for agricultural waste collection and transport network design in efficient waste management. The main contributions of the paper (Tran et al, 2023) include:

- Formulating a MINLP for the LARP in agricultural waste management.
- Applying a linearisation technique to transform the MINLP into a linear form that can be solved by any optimisation solver.
- Developing a PWFA for efficiently solving the large-sized instances of LARP.
- Applying the model and algorithm for solving a real case study in Trieu Phong district, Quang Tri province, Vietnam.

The model and algorithm have been referred to solve solid waste management problems by optimisation and simulation methods (e.g., Tosarkani et al., 2024; Dou et al., 2024; Hussain et al., 2024; Sadati et al., 2024). However, they have not applied to solve agricultural waste management problem at the Mekong Delta. To adapt the model and algorithm from Tran et al. (2023) for addressing the realistic characteristics of the Mekong Delta (road and river infrastructure, etc.), we need to consider the research question "how to integrate three following key characteristics in the mathematical formulation and algorithm development?":

- Both road and river networks are used for agricultural waste collection and transport.
- Multiple locations of waste treatment facilities are used to mitigate the impact of flood on the transport networks.
- Considering the impact of flood (i.e., disruption risk) on storage and facility locations and transport networks for sustainable agricultural waste management.

### 3. Aim and Objectives

This project aims to develop and implement a sustainable agricultural waste management model at the Mekong Delta (covering the region of Vietnam, Laos, and Cambodia) to stop burning the agricultural waste at fields and utilise the waste for bio-organic fertilizer, mushroom and biomass energy production. In addition, a strategic flood mitigation planning model is developed and integrated to mitigate the flood impact on agricultural waste management (or climate resilience).

To achieve the aim of this project, the following project objectives (Os) are planned:

- **O1**: Do a survey of economic, environmental, and social impact of climate change (e.g., flooding) for sustainable agricultural waste management at the Mekong Delta.
- **O2**: Adapt a mathematical programming model for planning flood mitigation strategies at the Mekong Delta.
- **O3**: Adapt a mathematical programming model for agricultural waste collection and transport network at the Mekong Delta.
- **O4**: Collect data to build a case study of sustainable agricultural waste management at the Mekong Delta for model implementation.
- **O5**: Organise one-day workshop to disseminate the findings and engage wider stakeholders.

The targeted outcomes (OCs) of this project consist of:

- **OC1**: Identify the practical needs and challenges of achieving sustainable agricultural waste management at the Mekong Delta.
- **OC2**: Mitigate the impact of flooding on the transport network of sustainable agricultural waste management at the Mekong Delta.
- **OC3**: Achieve sustainable agricultural waste management model at the Mekong Delta.
- **OC4**: Engage wider stakeholders from ASEAN government organisations (e.g., ministries) to the challenges at the Mekong Delta via the workshop.
- **OC5**: Engage international stakeholders to the challenges at the Mekong Delta via the workshop.

## 4. Research Methodology

This is an international research collaboration project between UK and France universities and ASEAN project partners, including:

- Cranfield University, UK (CU)
- University of Bedfordshire, UK (UoB)
- University of Loraine, France (UoL)
- Asian Management and Development Institute, Vietnam (AMDI)
- Institute of Meteorology, Hydrology and Climate Change, Vietnam (IMHEN)
- Vietnam National University of Agriculture, Vietnam (VNUA)
- National University of Laos, Laos (NUoL)
- Mekong River Commission Secretariat, Cambodia (MRCS)

Figure 1 shows a diagram of research methodology for collaborating and implementing research activities (in corresponding work packages) among project partners in this project. After completing WP1 (survey and interview) to understand the needs and challenges of sustainable agricultural waste management at Mekong Delta, we do WP2 to study the potential innovative alternatives for achieving the goal. After that, WP3 is done to build the case study that capture all the realistic characteristics of studying problem at Mekong Delta. Then, our optimisation team develops mathematical models and algorithms to solve the problem. Finally, we report the results and disseminate them at the final workshop.

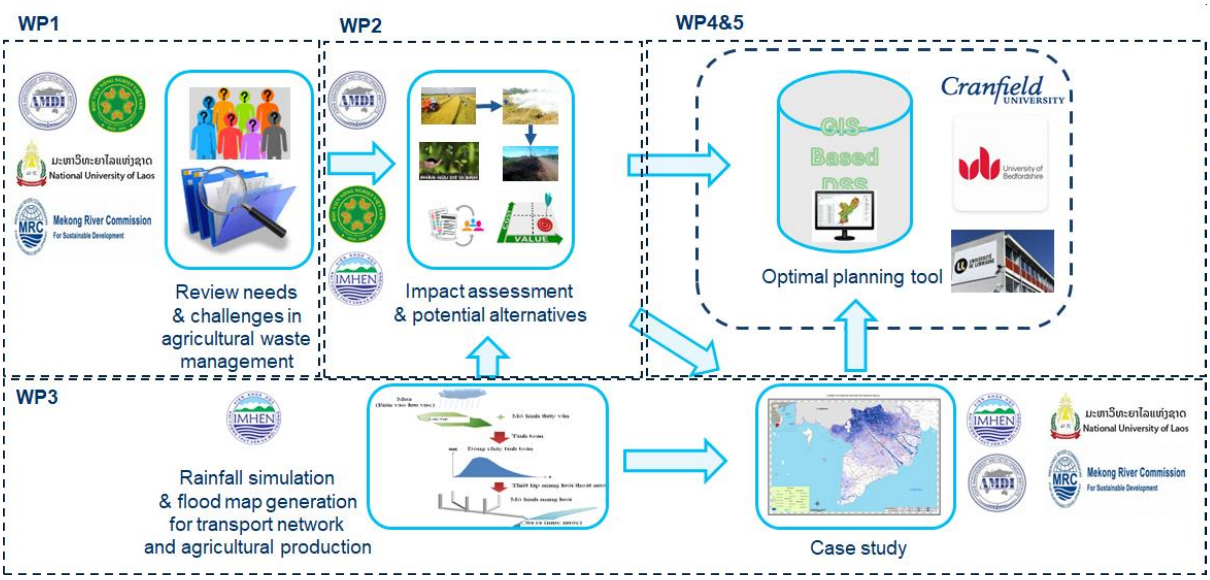


Figure 1: Research methodology diagram.

This project involves the ASEAN partners including Vietnam (Dr. Van from VNUA, Mrs. Be from AMDI, and Mr. Phung from IMHEN), Laos (Dr. Vatthanamixay from NUoL), and Cambodia (Mr. Hour from MRCS). During the project period, they support to do survey, to collect data for constructing the case study, and to adapt, deploy and service our product under the local conditions of ASEAN. They organize one workshop in September 2024 to present and disseminate the results for the case study.

The CU, UoB and UoL study and adapt our mathematical programming models and optimization methods for the local conditioned problems in the Mekong Delta. The models and methods are then computerized and embedded into an Integrated Decision Support System (IDSS). Using the Mekong Delta's flood maps generated by IMHEN, and the data of waste collection and transport network provided by the local partners, the IDSS is applied to generate a plan for sustainable agricultural waste management. The IDSS is deployed to test on the case study to ensure that it works correctly with the Mekong Delta's local conditions.

To achieve the aim of this project, five work packages (WPs) including the following research activities (RAs) are planned:

**WP1 (Feb'24 – Apr'24; AMDI, NUoL, MRCS and VNUE) – Survey:** An online survey is done by the ASEAN partners to study the economic, environmental, and social impact of climate change (i.e., flooding) on agricultural production and waste management at the Mekong Delta. In addition, this survey identifes the specific needs and challenges in sustainable agricultural waste management at the Mekong Delta. **Method: Online survey**.

*- RA 1.1: Conduct an online survey and send it to participants at the Mekong Delta in Vietnam, Laos, and Cambodia.*

*- RA 1.2: Study the characteristics of agricultural waste types, the challenges and approaches for building facilities that produce bio-organic fertilizer, mushroom and biomass energy from waste at the Mekong Delta.*

**WP2 (Apr'24 – Jun'24; AMDI, VNUE and IMHEN) – Evaluation and Solution:** A qualitative and quantitative analysis for the survey result is done to assess the impact and find potential alternatives. Digital solutions towards sustainable agricultural waste management at the Mekong Delta are investigated. **Method: Qualitative and quantitative analysis.**

*- RA 2.1: Assess the likelihood and impact of unexpected failures of location sites and road network due to flood impact on the performance of agricultural waste collection, transport, and treatment network in the Mekong Delta.*

*- RA 2.2: Study the digital solutions including technology to achieve sustainable agricultural waste management at the Mekong Delta.*

**WP3 (Feb’24 – Jul’24; IMHEN, AMDI, NUoL and MRCS) – Case study:** Relevant data for rainfall simulation and flood map generation under extreme weather conditions for the Mekong Delta are collected. In addition, other relevant data (such as field locations, the amount of agricultural waste at the fields, road network, waste types, storage locations and capacity, vehicle fleet, facility locations) for the design of agricultural waste collection and transport network at the Mekong Delta are collected. **Method: Data collection and simulation.**
*- RA 3.1: Collect data for rainfall simulation and flood map generation at the Mekong Delta.*
*- RA 3.2: Run the Mike Urban simulation software to generate the flood maps.*
*- RA 3.3: Collect data for constructing the case study of agricultural waste transport and treatment network at the Mekong Delta.*

**WP4 (Mar’24 – Aug’24; CU, UoB, and UoL) – Development and Implementation:** The proof-of-concept models from our previous projects are adapted to implement for the efficient agricultural waste management and flood impact mitigation at the Mekong Delta. The adapted models are applied for the case study of WP3. **Method: Mathematical Science and Information, Communication and Technology.**
*- RA 4.1: Adapt the mathematical models and solution methods from GCRF-OSIRIS and OPT-AWAMA for the case study at the Mekong Delta.*
*- RA 4.2: Code and solve the models in C++ using IBM ILOG CPLEX callable libraries.*
*- RA 4.3: Implement the coded models and solutions on the case study.*

**WP5 (Sep’24; all project members) – Report and Dissemination:** A final workshop is held in Ho Chi Minh City, Vietnam to report the outcomes and findings from this project. **Method: Report and Presentation.**
*- RA 5.1: Organize the 1-day workshop in Vietnam to disseminate the findings (Sep 2024).*
*- RA 5.2: Draft a technical report (Aug 2024) and a conference presentation (Dec 2024).*

Surveys for WP1 are provided in Appendices A – D. The results show that it is essential to build and implement a sustainable agricultural waste management model for addressing the challenges at the Mekong Delta. In the next sections, we report the findings from the surveys, and then present the case study and the mathematical models for the sustainable agricultural waste collection and transport network design.

## 5. Impact of Climate Change on Sustainable Agricultural Waste Management

### 5.1 Survey objectives and questions

The social, economic and environmental impact assessment aims to provide a realistic view of the effects of climate change on the agricultural production and waste management as well as to identify the specific needs and challenges in sustainable agricultural waste management at the Mekong Delta which will be used for the research models. The assessment considers social, environmental and economic impacts experienced by two groups in three countries:

- Farmers of assessment areas in three countries
- Drivers for waste collection

In addition, the online survey also expands the target respondents of some local enterprises working in areas of organic agricultural waste production and local agricultural authorities of An Giang province, Vietnam to serve development of a typical case study in Vietnam.

### 5.2 Survey methodology

#### 5.2.1 Survey design and modality

a) Quantitative survey

An online survey was conducted among residents in the Mekong Delta areas of Cambodia, Lao PDR, and Vietnam. The survey aimed to explore respondents' beliefs and opinions regarding the economic, environmental, and social impact of climate change on agricultural production and waste management in their respective regions.

b) Qualitative survey

A qualitative survey was conducted through desk research and in-depth interviews with local government personnel and relevant enterprises in An Giang province, Vietnam. The objective was to gain insights into the current situation and policies related to agricultural waste treatment and management. Furthermore, the data collected from this survey will used to construct a case study in the broader Mekong Delta region.

#### 5.2.2 Target respondents and survey sample sizes

a) Quantitative survey

For the quantitative survey, our target respondents primarily consist of low-income and vulnerable communities in the Mekong Delta region, spanning Cambodia, Lao PDR, and Vietnam. Specifically, we include individuals aged 18 years and older who reside in the designated areas within these three countries. The two main groups of interest are (1) farmers and (2) drivers associated with waste treatment facilities.

Table 2: Criteria to select the respondents.

| Included | Excluded |
|---|---|
| • At least 18 years of age<br>• Willing to consent to participate in the survey<br>• Know using smartphone to respond to survey | • Younger than 18 years of age.<br>• Not capable of responding to the survey<br>• Refuse to participate after 3 attempts of persuasion. |

Given the constraints of limited time, budget, and the online survey format, we can only focus on a restricted number of respondents in each country as outlined below:

Table 3: Respondents included in the sample.

| Category of respondents | Number of expected respondents | | |
|---|---|---|---|
| | Vietnam | Lao PDR | Cambodia |
| Farmers | 50 | 50 | 50 |
| Drivers for waste treatment facilities | 05 | 05 | 05 |
| Total | 55 | 55 | 55 |

b) Qualitative survey

The target respondents for the qualitative survey include local government staff from the An Giang Department of Agriculture and Rural Development (DARD) and the District Agricultural sub-department, as well as some local enterprises in An Giang province, Vietnam. The planned sample sizes for the qualitative survey are as follows:

- 01 DARD staff member
- 01 district agricultural division staff member from An Giang province, Vietnam
- 02–03 staff members from local enterprises working in the areas of agricultural waste management and treatment for bio-organic fertilizer.

### 5.2.3 Timeline and survey areas

- Time: from Apr to June 2024
- Study sites: Mekong Delta region of Cambodia, Lao PDR and Vietnam (An Giang)

### 5.2.4 Tools and data collection methods

Data is collected through a Google Form, which is then converted into a QR code for easy access via smartphones. The QR code provides a convenient way for participants to access the quantitative survey.

- **Pre-testing:** The quantitative questionnaires were pre-tested with a local resident to ensure accuracy. This included verifying successful redirection from the QR code to the Google Form and ensuring clarity in language and questionnaire meanings.
- **Data collection oversight:** AMDI and research leaders in Vietnam, Lao PDR, and Cambodia will closely monitor the data collection process. All collected data will be securely stored in Google Cloud at AMDI.
- **Quality assurance:** After data collection, AMDI will meticulously review 100% of the filled questionnaires to ensure cleanliness and validity before analysis.
- **Data labelling:** AMDI will label the collected data in English for reporting purposes.

### 5.2.5 Survey locations

- Cambodia: mainly in 5 districts and Phnom Penh
- Lao PDR: Various locations
- Vietnam: An Giang province

### 5.2.6 Sampling strategies

**Sampling and respondent selection**

In Cambodia and Lao PDR, we distributed online survey questionnaires via the WhatsApp application to target farmers and drivers in each respective country. Colleagues in both Cambodia and Lao PDR actively monitored and encouraged responses by phone. Meanwhile, researchers in these countries leveraged their networks to circulate the questionnaires.

Initially, our proposal outlined conducting online surveys (quantitative) across three countries, with the target respondents being farmers and waste drivers in the Mekong Delta region. However, we later narrowed our focus to An Giang province in Vietnam due to its earmarking for a future case study. In An Giang province, we conducted more in-depth interviews with local government staff and enterprises to gain a clearer understanding of the situation. This information will inform the development of our future model.

The criteria for identifying target respondents for the quantitative survey are as follows:

- Being farmers or drivers,
- Engaging in agriculture or livestock production,
- Dealing with agricultural waste production and treatment.

### 5.3 Survey strengths and constraints

#### 5.3.1 Survey strengths

Despite the online nature of our survey, the sample size remains quite small. Therefore, researchers can monitor and review each response individually, promptly addressing any misunderstandings or seeking clarifications from respondents to ensure accurate recording of responses.

#### 5.3.2 Survey constraints

During the implementation of the survey, we encounter several constraints that deviate from the original plan:

- **Limited time and budget:** Initially, the survey was scheduled to take place from November 2023 to December 2023. However, due to extended contract signing and inception activities, the project's actual start date shifted to February 2024. Notably, the Cambodia and Lao PDR Songkran festival begins on April 13th each year and lasts for two weeks. This further delayed the survey. Additionally, our budget for the survey is restricted, which impacts the design and execution of the survey. Given the budget constraints, we can only design an online survey and this approach comes with certain limitations such as: survey fraud, response bias, increase in errors, unanswered questions, difficulty interpreting sentiments etc.
- **Limited private enterprises working in the area of bio-organic fertilizer production and agricultural wastes recycle in An Giang province:** the research team can only meet with one representative of 01 cooperative working in at related areas for qualitative interviews instead of target 2-3 enterprises.

### 5.4 Survey results

#### 5.4.1 Quantitative survey results of farmers in three countries

The farmer interviewees constituted 100% of the total 150 respondents across all three countries, 24% female and 76% male. The gender distribution of respondents is as follows:

Table 4: Gender of respondents.

| Gender/Country | Cambodia | Lao PDR | Vietnam |
|---|---|---|---|
| Male | 29 | 45 | 40 |
| Female | 21 | 5 | 10 |
| Total | 50 | 50 | 50 |

#### 5.4.1.1. Perceived agriculture waste production toward sustainability

The target respondents for the online survey are farmers who own agricultural lands. Generally, Cambodia and Lao PDR have higher adoption rates of bio-organic fertilizer (56% and 100%, respectively) than Vietnam (0%). Lao PDR stands out with full adoption, utilizing agricultural wastes significantly (98%) for bio-organic fertilizer production. Vietnam's lack of adoption suggests potential for production of bio-organic fertilizers from agricultural wastes.

Table 5: Perceived using of bio-organic fertilizer.

| Country | Total farming areas of surveyed households (ha) | Average farming areas of surveyed households (ha) | % of using bio-organic fertilizer | % agricultural wastes used to produce bio-organic fertilizer |
|---|---|---|---|---|
| Cambodia | 105,1 | 2,1 | 56% | 40% |
| Lao PDR | 115,41 | 2,3 | 100% | 98% |
| Vietnam | 69,78 | 1,4 | 0% | 0% |

The following figure demonstrates that during the process of agricultural production, Cambodia and Vietnam have significant straw waste generation, while Lao PDR has universal straw waste production. Duckweed waste is negligible across all three countries. Manure waste is prevalent in both Cambodia and Lao PDR. Other scraps and by-products vary, with Cambodia having the lowest and Lao PDR the highest generation.

Table 6: Types of wastes generated from agricultural production in three countries.

| Country | Straw | Duckweed | Manure | Other scraps, by-products |
|---|---|---|---|---|
| Cambodia | 41/50 | 0 | 28/50 | 10/50 |
| Lao PDR | 50/50 | 0 | 50/50 | 14/50 |
| Vietnam | 48/50 | 1/50 | 0 | 16/50 |

Among farmers experienced in agricultural waste treatment in Cambodia and Lao PDR, the minimum storage period for Cambodian farmers was shorter than that for Laotian farmers (1-2 months vs. 3-5 months). Moreover, over two-thirds of Laotian respondents reported being able to store waste for more than 6 months, while only 10% of Cambodian respondents could do so. The shortest distance between the collection area and the composting site was similar for both Laos and Cambodia (less than 1 km). However, 6% of Lao PDR respondents found it inconvenient to access the composting site beyond 5 km, whereas approximately two-thirds of Cambodian farmers could travel within only 5 km.

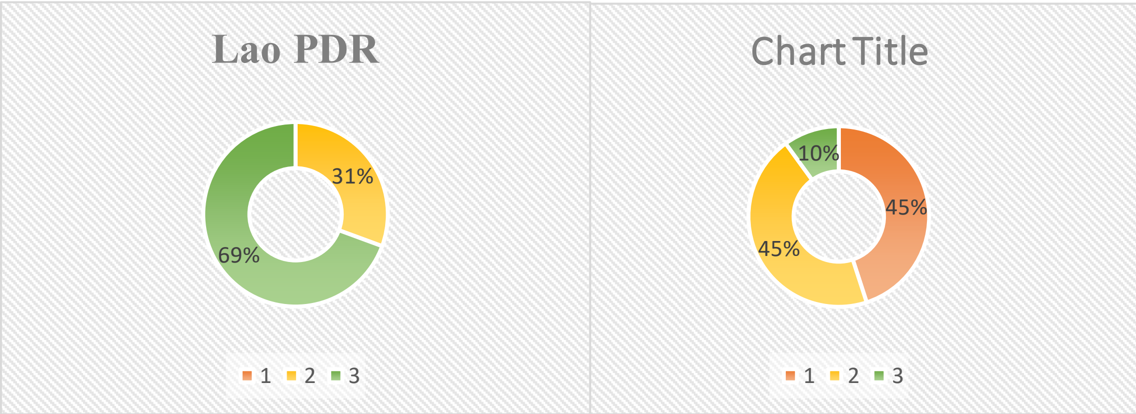


Figure 2: Storage period of agricultural wastes in Lao PDR and Cambodia.

In terms of the total cost for the annual collection of agricultural waste (including wages, transportation, collection, and storage), half of the Lao PDR participants spent between 0.6 and 1 million Kip per year on the collection process; Two-fifths spent less than 0.5 million Kip; Only about one-tenth had to pay the higher amount (2 to 3 million Kip) for waste collection. For Cambodia, 70% of surveyed Cambodian farmers paid less than 500,000 KHR for waste collection; 10% paid between 500,000 and 1 million KHR. Interestingly, one-fifth of respondents incurred no cost during this process.

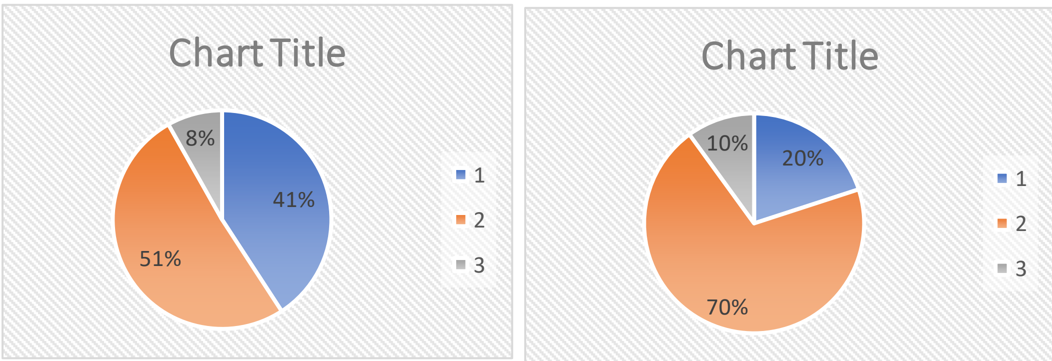


Figure 3: Cost for agricultural waste collection per year.

Among the Cambodian farmers producing bio-organic fertilizers from agricultural wastes, only 4% sold at the prices of 1.4 to 1.5 million Kip per ton.

The table below illustrates how survey participants from the three countries managed their agricultural waste instead of producing bio-organic fertilizers. Vietnamese respondents sold agricultural waste generated from production to three groups (i) Other households (27 out of

50) at prices ranging from 200,000 to 530,000 VND per ton; (ii) Local cooperatives (7 out of 50) at prices between 470,000 and 530,000 VND per ton; and (iii) Private enterprises (8 out of 50) at prices from 300,000 to 530,000 VND per ton. In Lao PDR, 35 out of 50 participants kept their agricultural waste for personal use. The remaining participants sold waste at prices ranging from 300,000 to 1.66 million Kip (without specifying the buyers). In Cambodian, farmers allowed three groups to collect their agricultural waste. However, 33 respondents did not mention prices, while 17 sold waste at a wide range of prices, from 70,000 up to 14 million KHR per ton.

Table 7: Alternatives for agricultural waste treatment.

| Country | Selling to other households | Selling to local cooperatives | Selling to private enterprises | Keeping for personal use | Other options |
|---|---|---|---|---|---|
| Cambodia | 28/50 | 8/50 | 8/50 | - | Burning (2/50) |
| Lao PDR | - | - | - | 35/50 | Selling without mentioning the buyers (15/50) |
| Vietnam | 27/50 | 7/50 | 8/50 | - | Burning (19/50) |

When it comes to vehicles for transporting agricultural waste, the wheelbarrow was the most widely used method for waste transportation in all three countries. Following the wheelbarrow, small farm vehicles were commonly used for waste transport. Nearly a quarter of Cambodian respondents used bullock carts for waste transportation. However, this method was less popular among Vietnamese farmers, with only 2% opting for it. Less than one-fifth of both Cambodian and Lao PDR participants transported waste using cars.

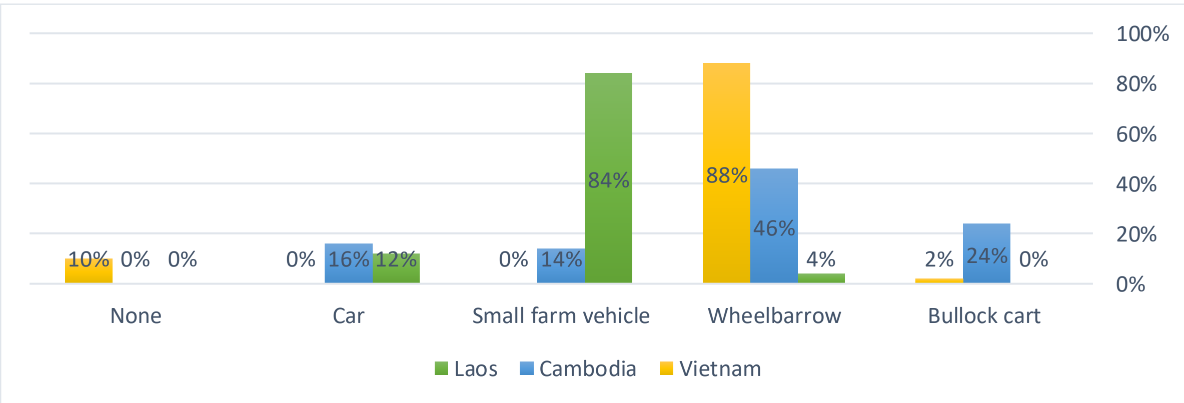


Figure 4: Types of vehicles for transporting agricultural wastes.

According to the table below, the lack of collecting vehicles and transportation difficulties were the major challenges in collecting agricultural waste among all respondents. Specifically, 40 out of 50 Lao respondents found it difficult to access collecting vehicles for waste collection. Labor shortage was also an obstacle for farmers from Lao PDR and Cambodia (33 and 25 respondents, respectively). In addition to distance and transportation difficulties, Vietnamese participants faced challenges related to the absence of agricultural waste collection organizations in their neighbourhoods (13 out of 50), followed by a lack of storage (11 out of 50) and inadequate agricultural waste treatment facilities (10 out of 50).

Table 8:Difficulties in producing bio-organic fertilizers from agricultural wastes.

| Difficulty | Cambodia | Lao PDR | Vietnam |
|---|---|---|---|
| Lack of collecting vehicles | 11/50 | 40/50 | 09/50 |
| Long distance and difficulty in transportation | 10/50 | 22/50 | 19/50 |
| Lack of labour | 25/50 | 33/50 | 01/50 |
| Lack of storage | 15/50 | 7/50 | 11/50 |
| Lack of agricultural waste treatment facilities | 8/50 | 5/50 | 10/50 |
| Lack of agricultural waste collection organizations | 7/50 | 11/50 | 13/50 |
| Other difficulties (inc., little waste, near the houses) | 2/50 | | |
| None | | | 06/50 |

#### 5.4.1.2. Perceived climate change

Most Lao PDR and Vietnamese farmers were aware of climate changes (100% and 96%, respectively) compared with 78% of Cambodian farmers. Among survey participants, a small minority of the respondents assumed that climate change caused no adverse effects. Climate change results in heavier and prolonged rains are considered the main effects of climate change. Cambodia experiences heavier rain in 15 out of 50 cases, while Lao PDR and Vietnam have even more frequent heavy rain (47/50 and 5/50 cases, respectively). Cambodia has prolonged rain in 3 out of 50 cases, whereas Lao PDR and Vietnam experience it more often (17/50 and 14/50 cases, respectively). This suggests that climate change is contributing to increased rainfall intensity in these regions. It seems that higher frequency of short-term rainfall become more intense and frequent events as 22/50 respondents in Cambodia, 19/50 respondents in Lao PDR and 6/50 respondents in Vietnam. 7/50 cases in Vietnam mentioned that climate changes cause erratic weather. Cambodia experiences less rain in 6 out of 50 cases, while Vietnam reports it in 15 out of 50 cases. The reduced rainfall could be linked to climate change-induced shifts in precipitation patterns. Cambodia and Vietnam mention other effects (e.g., unseasonal rain, less sunlight) in 3 out of 50 and 7 out of 50 cases, respectively. The additional impacts highlight the complexity of climate change's influence on weather.

Table 9: Effects of climate change on the weather.

| Effects | Cambodia | Lao PDR | Vietnam |
|---|---|---|---|
| Does not cause any adverse effects | 4/50 | | 1/50 |
| Result in heavier rain | 15/50 | 47/50 | 5/50 |
| Result in more prolonged rain | 3/50 | 17/50 | 14/50 |
| Result in higher frequency of rainfall in a short period | 22/50 | 19/50 | 6/50 |
| Erratic weather | | | 7/50 |
| Less rain | 6/50 | | 15/50 |
| Drought | 1/50 | 1/50 | |
| Other effects (e.g., unseasonal rain, less sunlight) | 3/50 | | 7/50 |

The study shows that 100% of Lao PDR farmers felt climate change's impact on their agricultural production compared to 58% of Cambodian and 78% Vietnamese respondents, specifically **flooding and drought**. Lao PDR was the most affected by **flooding** (47/50 cases) while Vietnam suffered from drought (31/50). Cambodia was affected by these both types of disasters **(flooding** 44% vs drought 56%).

Table 10: Impacts of climate change on agricultural production.

| Country | Flooding | Drought | Soil salinity | None |
|---|---|---|---|---|
| Cambodia | 17/50 | 23/50 | 0 | 0 |
| Lao PDR | 47/50 | 3/50 | 0 | 0 |
| Vietnam | 21/50 | 31/50 | 0 | 1/50 |

Based on survey result, flooding is considered one of the most serious impacts of climate change on agricultural production. The following sections will assess additional social, economic, and environmental impacts caused by flooding in agriculture.

#### 5.4.1.3. Economic impacts caused by flood

Economic impacts caused by flood were assessed based on perceived damage to plants, damage to productivity, sharply increasement of pests and diseases and others.

In terms of specific impacts of flooding on agricultural production, reduced productivity can be the most widely seen in the 03 countries, followed by damaged plants and sharply increase of pests and diseases. Still, up to about one third of Cambodian farmers and an insignificant number of Vietnamese respondents felt unaffected by any mentioned impacts.

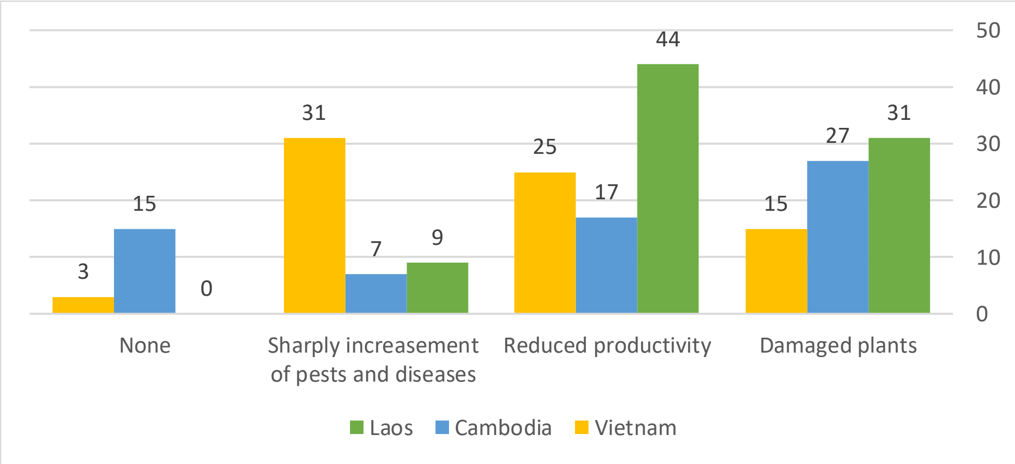


Figure 5: Impacts of flooding on agricultural production.

According to the figure below, it can be seen that a majority of respondents experienced flooding in their agricultural production from 1 to 3 recent years, especially in Lao PDR (up to 52%). There was still a group of Cambodian and Vietnamese farmers who had not suffered from flooding (38% and 66%, respectively).

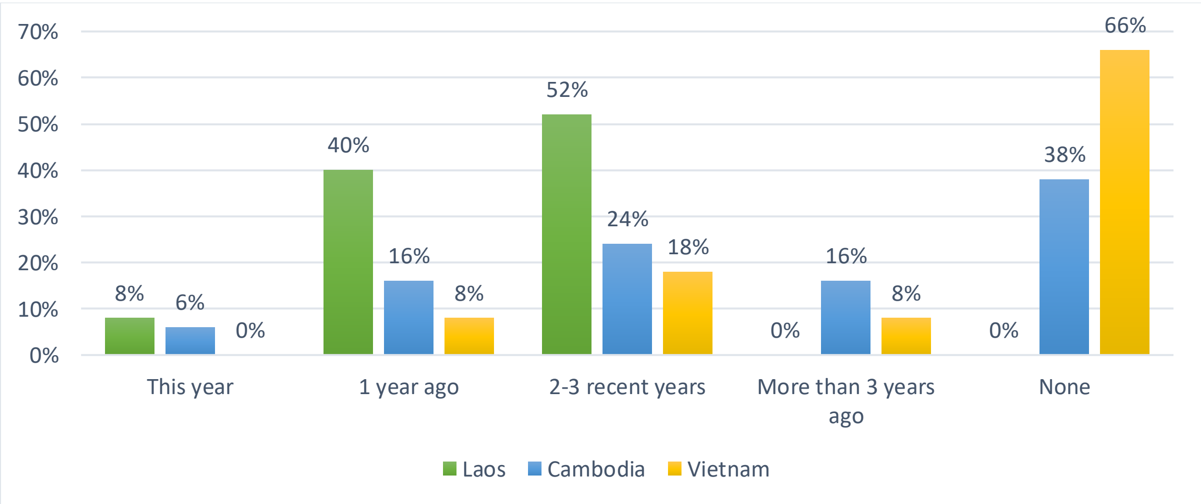


Figure 6: Flooding experience in agricultural production.

The study shows that 58% of Lao PDR respondents had their field flooded from 0.3-0.5m and can even reach the level of 1 meter (20%). More than half of Cambodian and Vietnamese farmers experienced the same flooding levels (0.2m and from 0.3 to 0.5m). 4% of Cambodian and 18% of Lao PDR participants suffered from the flooding of 0.5 to 1m.

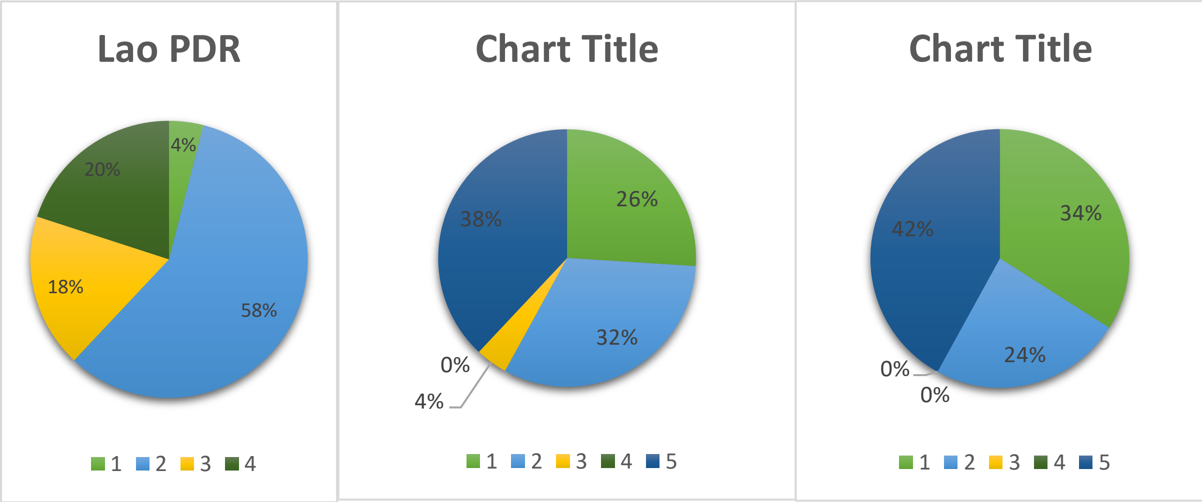


Figure 7: The flooding level of farmers' field in water.

Among Lao PDR respondents affected by last year's flood, 60% of respondents lost under 1 million Kip, 36% lost from 1.5 to 5 million Kip. 20% of Cambodian farmers lost under 1 million KHR, 26% from 1.5 up to 12 million KHR. 12% of Vietnamese farmers lost under 1 million VND, 12% from 1.2 to 5 million VND, compared to 4% above 12 million VND. However, over half of Cambodian and Vietnamese farmers suffered no economic damage (54% and 72%, respectively) compared to 2% of Lao PDR respondents.

In terms of flood impact on the farmers' family income, Lao PDR and Vietnamese respondents felt the most affected by reduced quality and devaluation of their products (48 and 30, respectively) while 22 of 50 Cambodian farmers found it difficult to plant for a long time. Late harvest was also a challenge for Cambodian and Vietnamese respondents (20 and 24, respectively). However, 20 Cambodian and 12 of Vietnamese participants saw no economic impacts from flooding.

Table 11: Flood impacts.

| Impacts | Cambodia | Lao PDR | Vietnam |
|---|---|---|---|
| Cannot plant on the field for a long time | 22 | 14 | 2 |
| Cannot harvest on time | 20 | 7 | 24 |
| Reduced quality and devaluation | 7 | 48 | 30 |
| None | 20 | 0 | 12 |
| Other effects (difficult for production) | 0 | 1 | 0 |

While about two-thirds of Cambodian respondents were not off from work compared to 22% in Vietnam due to floods, Lao PDR farmers spent at least 1 day staying at home. The largest ratio of participants taking from 1 to 7 days off from farming work were from Lao PDR (90%), followed by Vietnam (68%) and Cambodia (28%). All 3 countries had the same ratio of 10% of farmers taking more than 7 days up to 1 month off.

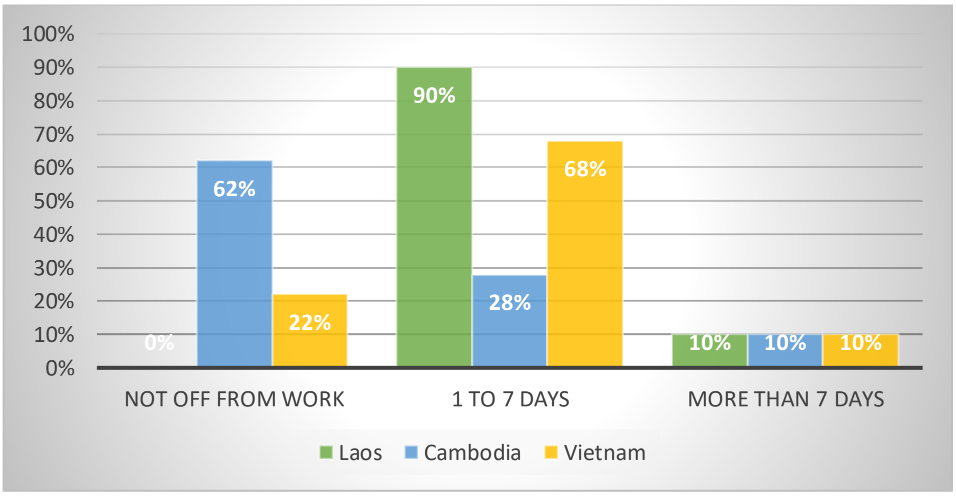


Figure 8: Number of days off from work due to floods.

### 5.4.1.4. Environmental impact caused by flood

When flooding occurs, solid wastes and wastewater were the most widely seen factors causing pollution in all participants' residence. The highest number of Vietnamese farmers saw their residence polluted by solid wastes, followed by wastewater (32/50) and carcasses (5/50). In Lao PDR, 31 respondents suffered from solid wastes, then wastewater (20/50). For Cambodia side, wastewater was the greater risk (22/50) compared to solid wastes (9/50). However, 19 Cambodia respondents saw no issues in flooding season compared to 5 Vietnamese respondents.

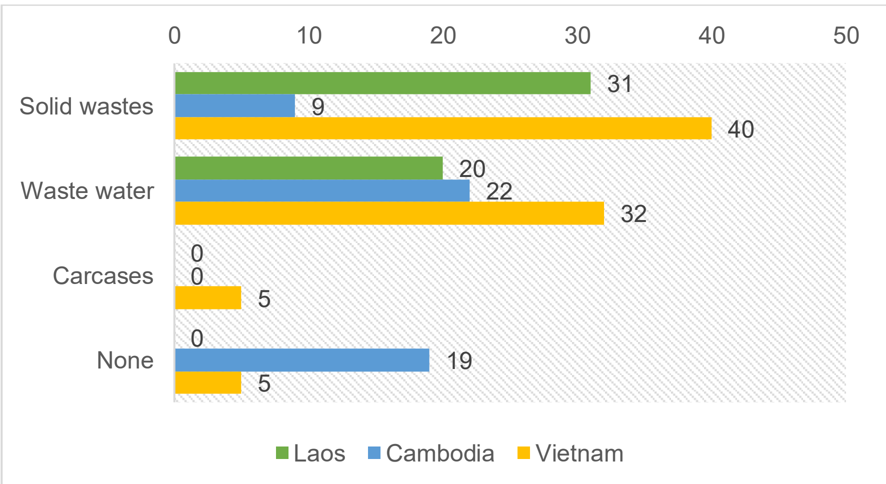


Figure 9: Pollution factors in the farmers' residence.

After prolonged downpour, 100% of Lao PDR farmers felt the presence of stench while 66% of Vietnamese and 62% of Cambodian respondents did. In Lao PDR, stench was mostly thought to come from overflow of polluting rivers/arroyos/reservoirs/canals (31/50) and wastes (30/50). For people who can feel the stench, in Cambodia, 22 respondents assumed wastes caused stench while 9 blamed for the polluting water resources. For Vietnam, 27 participants thought of wastes as the main reason for stench, as compared to 15 thoughts of overflow of polluting rivers/arroyos/reservoirs/canals in Cambodia, 22 respondents assumed wastes.

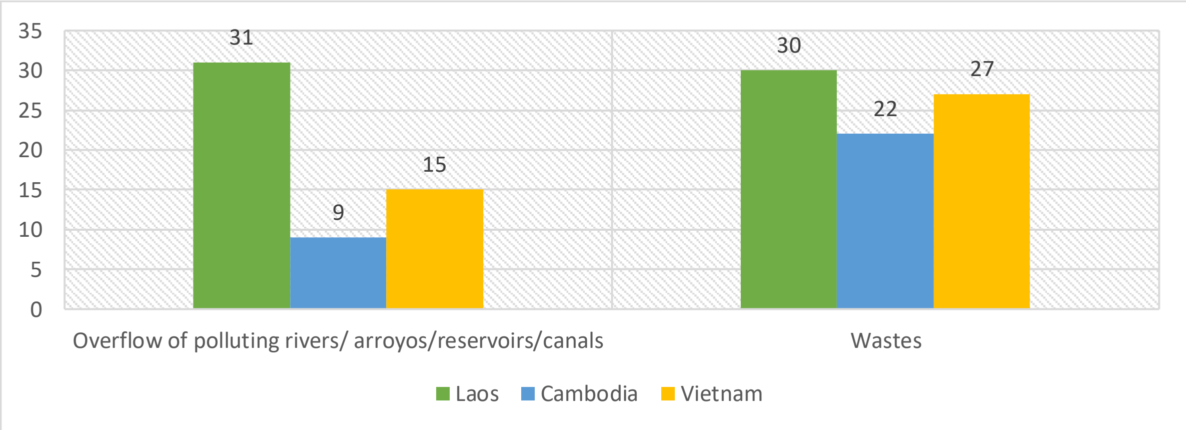


Figure 10: Sources of stench after prolonged downpour.

The most widely known impacts of environmental pollution included poor hygiene of the local living environment and the outbreak of various epidemics, especially in Lao PDR (30 and 45 participants) and Vietnam (42 and 21, respectively). Polluted environments can lead to poor health and increased cost of health treatment in Lao PDR and Cambodia (14 each). For 13 Cambodian farmers, the gradual death for green trees was a very concerning effect of environmental pollution, however, a similar group thought it caused no problem.

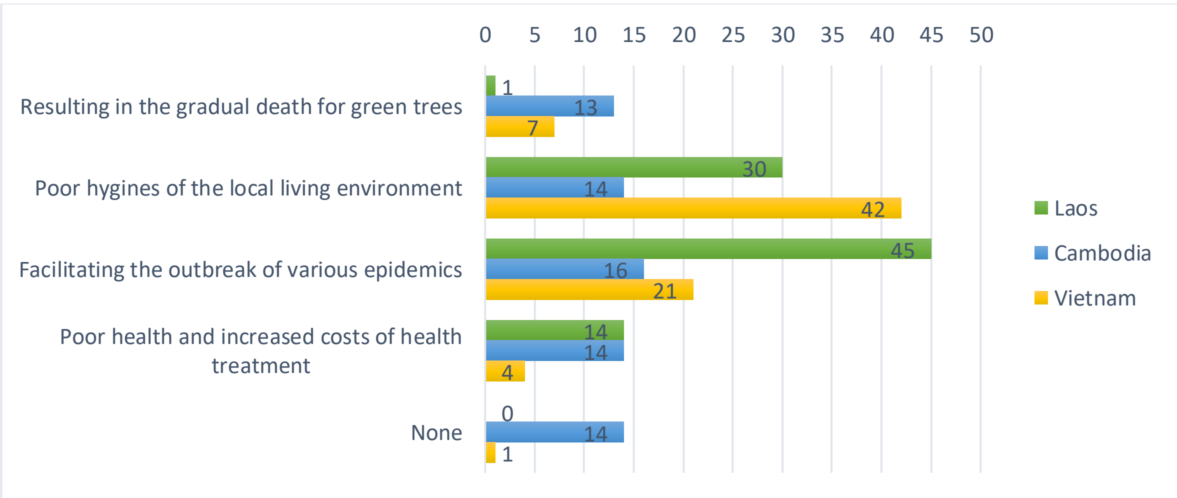


Figure 11: Impacts of environmental pollution.

During and after the flooding period, the following findings highlight variations in disease prevalence across the three countries during the flooding period. Skin diseases were particularly common in all three countries. Other diseases such as pinkeye, dengue are also noted in three countries. Diarrhoea cases were observed in Cambodia and Vietnam, but not in Lao PDR.

Table 12: Common diseases during the flooding period.

| Diseases | Cambodia | Lao PDR | Vietnam |
|---|---|---|---|
| Skin diseases (athlete's foot, scabies, impetigo, etc.) | 14/50 | 50/50 | 26/50 |
| Pinkeye | 7/50 | 3/50 | 4/50 |
| Dengue | 13/50 | 3/50 | 16/50 |
| Diarrhoea | 13/50 | 0 | 8/50 |
| Respiratory diseases (sore throat, flu, bronchitis, etc.) | 8/50 | 0 | 16/50 |
| Hand, foot and mouth diseases | 0 | 0 | 1/50 |
| None | 18/50 | 0 | 1/50 |

#### 5.4.1.5. Social impacts caused by flood

When asked how floods impact, deep floods impeding the transportation in Cambodia, Lao PDR and Vietnam (49, 29 and 40 respectively) is considered the most serious impacts. 31 Lao PDR farmers felt more affected by difficult transportation, traffic jam in many hours. These findings highlight the significant impact of floods on transportation networks, including delays, road closures, and traffic disruptions. Addressing these challenges is crucial for maintaining resilient transportation systems during flood events.

Table 13: Impacts of floods on transportation systems.

| Indicator | Cambodia | Lao PDR | Vietnam |
|---|---|---|---|
| Deep flooding water impeding the transportation | 49/50 | 29/50 | 40/50 |
| Difficult transportation, traffic jam in many hours | 4/50 | 31/50 | 6/50 |
| Depending on the flooding level | 0 | 0 | 4/50 |

During each flood season, less than half of Cambodian farmers (40%) cannot let their children go to school compared to 26% and 12% of Lao PDR and Vietnamese respondents, respectively. On average, about one quarter of Lao PDR respondents' children had to be absent 1 day from school in comparison with 10% of Cambodian farmers. 30% of participants in both countries took 2-day absence while only 17% of Vietnamese farmers did the same.

For an absence of 3-5 days, there were over one-third of respondents in Lao PDR compared to 17% in Vietnam. Only in Vietnam, 66% of farmers let children be absent over 1 week while those in the remaining 2 countries took 1 week maximum (Lao PDR 8% vs Cambodia 25%).

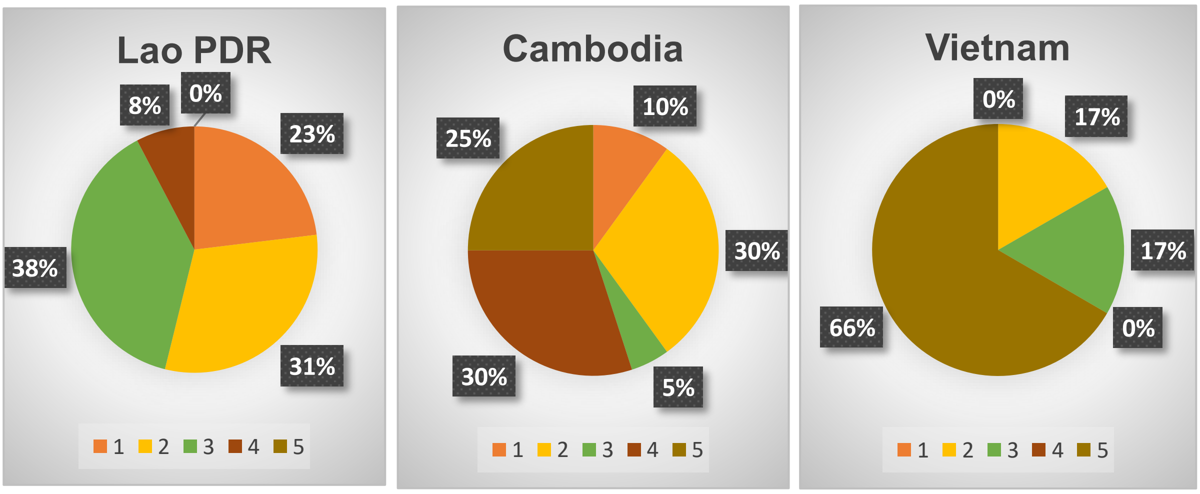


Figure 12: Numbers of days off from school during flooding season.

During the flooding time, a vast majority of farmers in Lao PDR (88%) faced with difficulties in approaching the healthcare stations compared to those in Cambodia (26%) and Vietnam (12%). In addition to medical services, over half of Lao PDR respondents also found it challenging in accessing cultural services while a smaller amount of Cambodian and Vietnamese faced with the same problem. Also, postal services and ward/district administrative procedures were also inaccessible for this country's farmers (21 and 16, respectively). Participants having no issues with accessing these services comprised a significant proportion in Vietnam (39/50) and Cambodia (30/50).

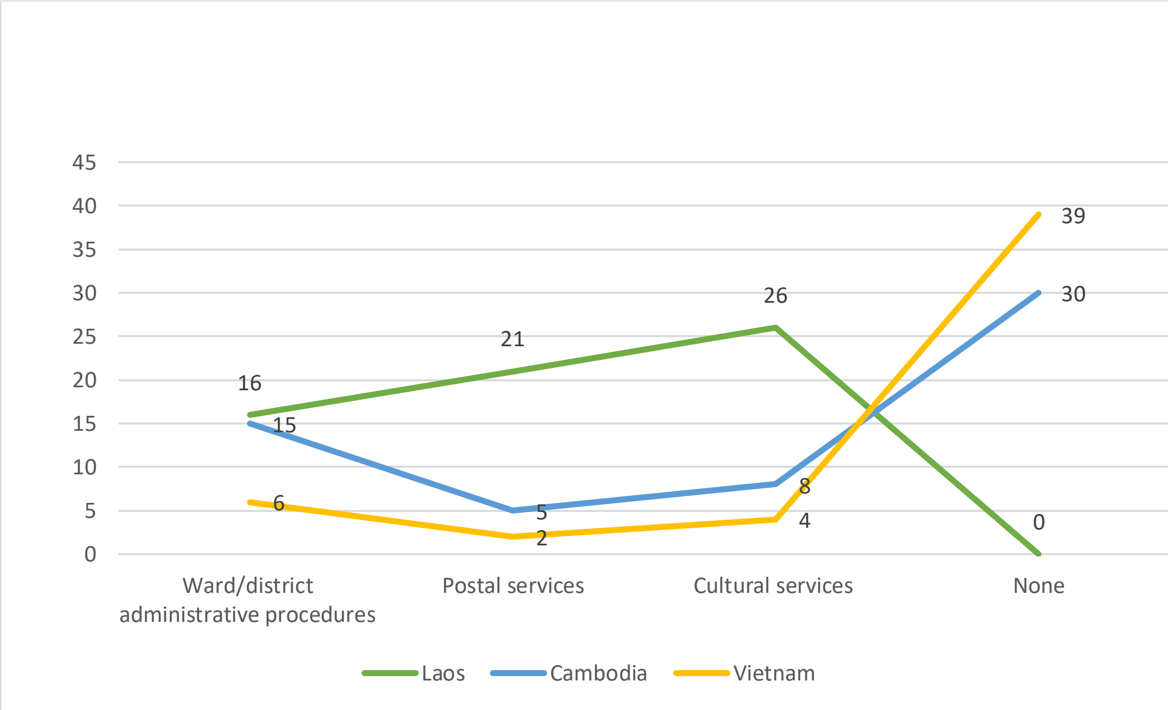


Figure 13: Difficulties in approaching public service due to flooding.

According to the Table below, difficulty in transportation constituted the largest ratio among the social impacts of flooding in all three countries, followed by prolonged traffic congestion and Children's absence from schools. Like the findings on the Figure above, a greater amount Lao PDR respondents faced with difficulties in accessing healthcare services and other public services than farmers in Cambodia and Vietnam.

Table 14: Social impacts due to flooding.

| Indicator | Cambodia | Lao PDR | Vietnam |
|---|---|---|---|
| Prolonged traffic congestion at severely flooded hotspots | 24/50 | 35/50 | 14/50 |
| Children's absence from schools | 17/50 | 40/50 | 2/50 |
| Difficulty in access to healthcare services | 4/50 | 19/50 | 1/50 |
| Difficulty in access to other public services (administrative procedure, security, postal services, etc.) | 8/50 | 14/50 | 1/50 |
| Weaker community cohesion | 5/50 | 9/50 | 11/50 |
| Difficulty in transportation including transportation of the agricultural products and wastes | 25/50 | 32/50 | 32/50 |

Due to the floods, up to 80% of participants in Lao PDR found it difficult in transporting agricultural waste to treatment facilities compared to 48% and 30% of those in Vietnam and Cambodia, respectively.

#### 5.4.1.6. Perceived solutions toward agricultural waste management

While 100% of Vietnamese respondents and almost all Lao PDR participants (98%) agreed with the necessities of collecting agricultural wastes for bio-fertilizer production and having the treatment facilities for agricultural wastes, just over three quarters of Cambodian farmers shared the same idea (76% and 78%, respectively).

The Figure below demonstrated the reasons why the farmers wished to produce bio-organic fertilizer. Accordingly, the most popular cause was to serve the agricultural production, then the better soil quality brought by the bio-organic fertilizer. Saving cost was also a proper reason seen at nearly half of farmers in both Vietnam and Cambodia. In addition, bio-organic fertilizer production can help protect the environment, which was chosen by 28 of 50 Vietnamese respondents. However, there was still a small group of Cambodian farmers showing no interest in producing bio-organic fertilizers.

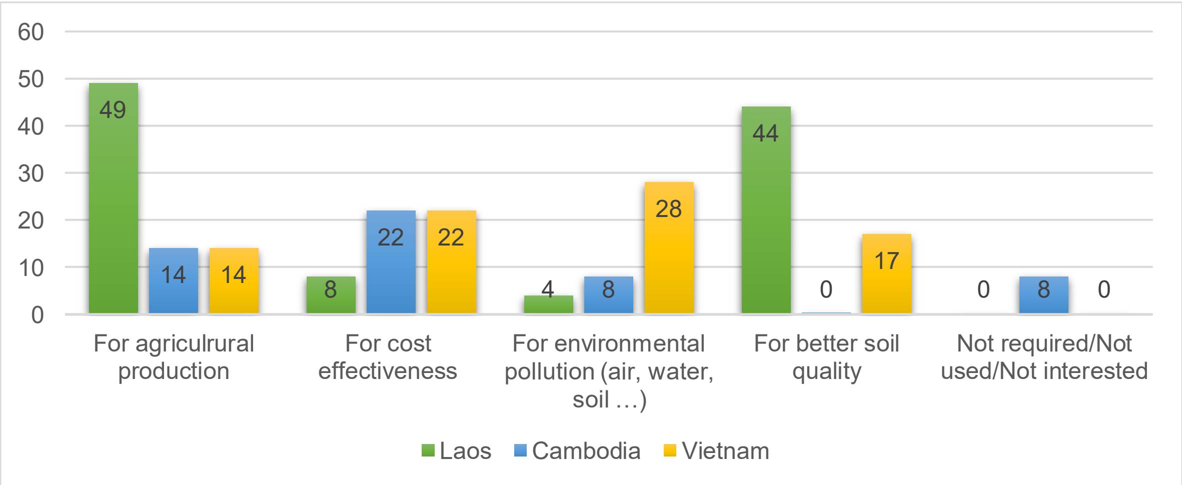


Figure 14: Reasons for producing bio-organic fertilizers.

In terms of the proper location of waste treatment facilities, in Vietnam, up to 86% of participants wished the facilities to stay far away from their residence while 10% wished them to stay near the fields. For Lao PDR side, 44% of respondents wanted the facilities to be located somewhere far away from 2km up to 9km from the community. While 28% of farmers wanted the facilities to be located at a safe place unlikely to be flooded, 18% had no specific suggestions. In Cambodia, in contrast to 44% of Lao PDR farmers, up to 40% of respondents wished facilities to stay near the village. 38% of participants suggested them to be located near the fields. About 12% of farmers wished the facilities to be built somewhere in the district.

Table 15: Perceived location to put waste treatment facilities.

| Locations | Cambodia | Lao PDR | Vietnam |
|---|---|---|---|
| Far away from the community (e.g., houses, market, etc.) | 2% | 44% | 86% |
| Near the field/sources of wastes | 38% | 8% | 10% |
| Near the houses/village | 40% | 0% | 0% |
| As regulated by the government | 0% | 0% | 4% |
| Somewhere safe, convenient, not flooded | 0% | 28% | 0% |
| Anywhere possible | 0% | 18% | 0% |
| Other places (district, downtown, fertilizer production area) | 12% | 2% | 0% |
| NA | 8% | 0% | 0% |

### 5.4.2 Quantitative survey results of drivers in three countries

The assessment also considered the perception of waste collection and treatment, as well as the impacts of climate change and flooding on waste collection drivers in three countries. These drivers include those whose work is closely related to waste collection and treatment and who are particularly exposed to floods. Among the respondents, 100% of Cambodian drivers and waste collectors were male, compared to 80% in both Lao PDR and Vietnam. In terms of age, Cambodian respondents were quite young, ranging from 22 to 32, while Lao PDR participants' ages ranged from 36 to 57, and Vietnamese drivers' ages ranged from 35 to 46. All waste collection drivers are working for public waste collection companies in three countries to collect daily domestic wastes.

In terms of waste volume, Cambodian drivers can transport 10 to 20 tons per day using garbage trucks. The trash collected is not agricultural waste and is not sorted for recycling. Meanwhile, in Lao PDR, 60% of respondents use manual dustcarts, while 40% use garbage trucks. Collectors using manual dustcarts collect 1.7 to 1.8 tons each day, while truck drivers transport at least 14 to 16 tons of waste. Among these drivers and collectors, only one participant collects agricultural waste. The number of respondents who realize that waste is partly or completely sorted for recycling is the same (2 for each). On the Vietnam side, 80% of respondents use manual dustcarts, and 20% use garbage trucks. Collectors using manual dustcarts collect 1 to 5 tons per day, while truck drivers transport 11 tons of waste. 40% of participants collect agricultural waste. Only one respondent realizes that waste is sorted for recycling.

According to participants from Cambodia and Laos, the destination of wastes in both countries was landfills while for Vietnamese drivers/waste collectors, wastes were transported to landfill (80%) and dumping site with treatment factory (20%). The distance from the waste collection area to the waste treatment place was basically similar between respondents in Lao PDR (ranging from 5 to 20km) and Cambodia (6 to 17km) while that in Vietnam was shorter (2 to 10km).

Under flooded conditions, slow move or temporary stop of vehicles in deeply flooded streets was the major reason for waste collectors/drivers in collecting wastes (Vietnam 5/5 vs Lao PDR 3/5). For four out of five Laos drivers/collectors, the second main reason can cause difficulties was prolonged traffic congestion and congestion due to flooding while two Cambodian respondents faced the same issue. In addition, 2/5 Cambodian drivers encountered no challenge during flooding days while the same number of Laos participants still struggled with vehicle breakdown/engine stalling.

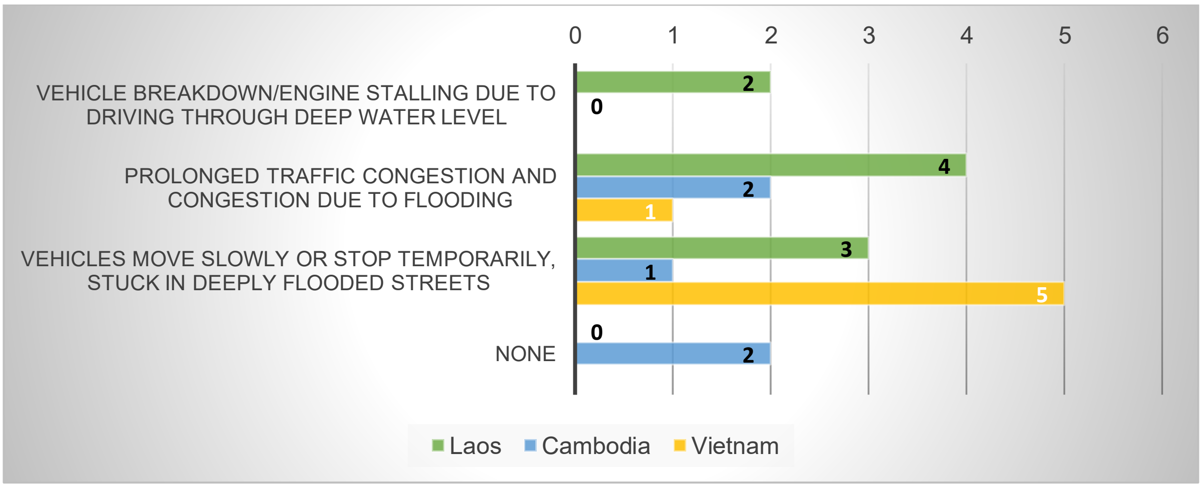


Figure 15: Difficulties encountered under flooded conditions.

All Cambodian drivers were not aware of any agricultural waste treatment areas compared to 80% of Laos and Vietnamese respondents. The study shows that 80% of Lao PDR participants had to face the flooding issue at their regular locations of collecting wastes while 40% of Cambodian respondents and 60% of Vietnamese did. 50% of Lao PDR respondents saw these collection areas flooded at only below 0.2m while the remaining half witnessed the water level of 0.3 to 0.5m and even above 1m (25% each). Meanwhile, all Cambodian drivers saw their collection area flooded at 0.3 to 0.5m. 80% of Vietnamese participants witnessed the water level of 0.3 to 0.5m while the remaining faced no flooding issue.

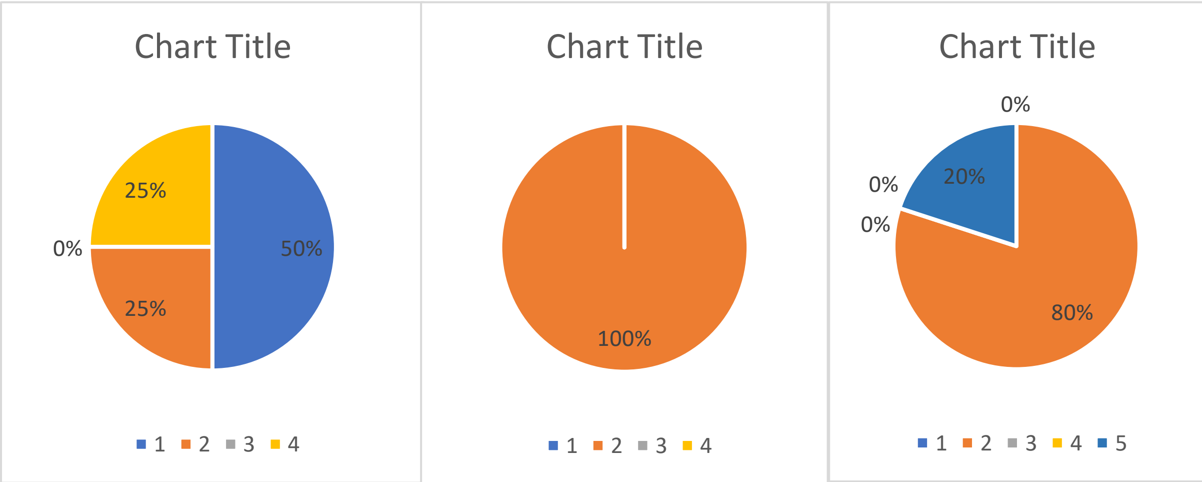


Figure 16: Flooding level at the areas of waste collection.

The flooding season did not last longer than 3 days in all three countries. While only 20% of Lao PDR and 40% of Vietnamese respondents chose 1 day, it could last less than 1 day or 3 days maximum (Lao PDR and Cambodia 40% each vs Vietnam 20%, each). One-fifth of Cambodian and Vietnamese drivers assumed they did not have a flooding season.

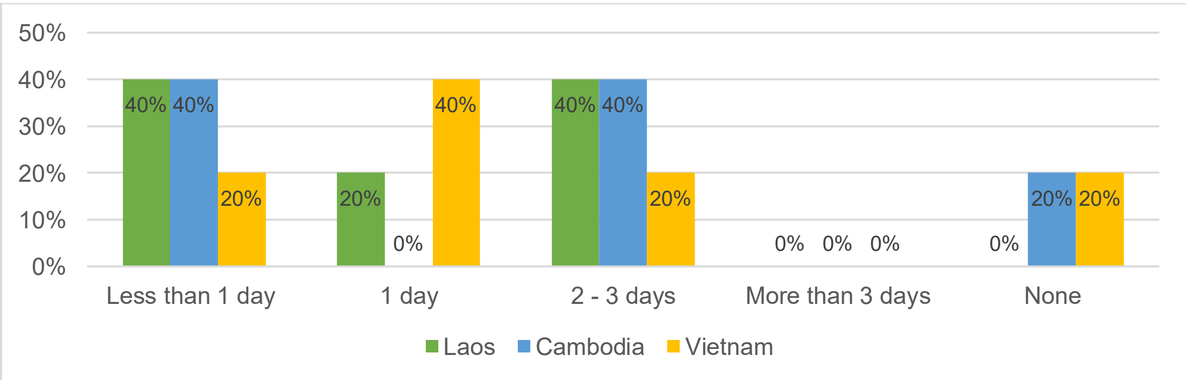


Figure 17: Length of flooding season.

While all Cambodian participants still worked as usual, 40% of Lao PDR respondents took 2-3 days and 3 days maximum off from work due to floods (20% each). 60% of Vietnamese participants took 1-3 days off from work.

All of Lao PDR and Vietnamese drivers/waste collectors heard of climate change while less than half of Cambodia respondents did. In terms of climate change's effect on the weather, heavier rain was thought to be the most noticeable one for Laos and Vietnamese respondents (5 and 4, respectively) compared to only 1 participant in Cambodia. The second major effect was more prolonged rain (Vietnam 4/5 vs Lao PDR 3/5) while no Cambodian driver shared the same idea. In addition, climate change also resulted in the higher frequency of rainfall in a short time (Cambodia 3/5 vs Lao PDR 2/5 vs Vietnam 1/5). However, there was one Cambodia respondents concluding climate change caused no adverse effects.

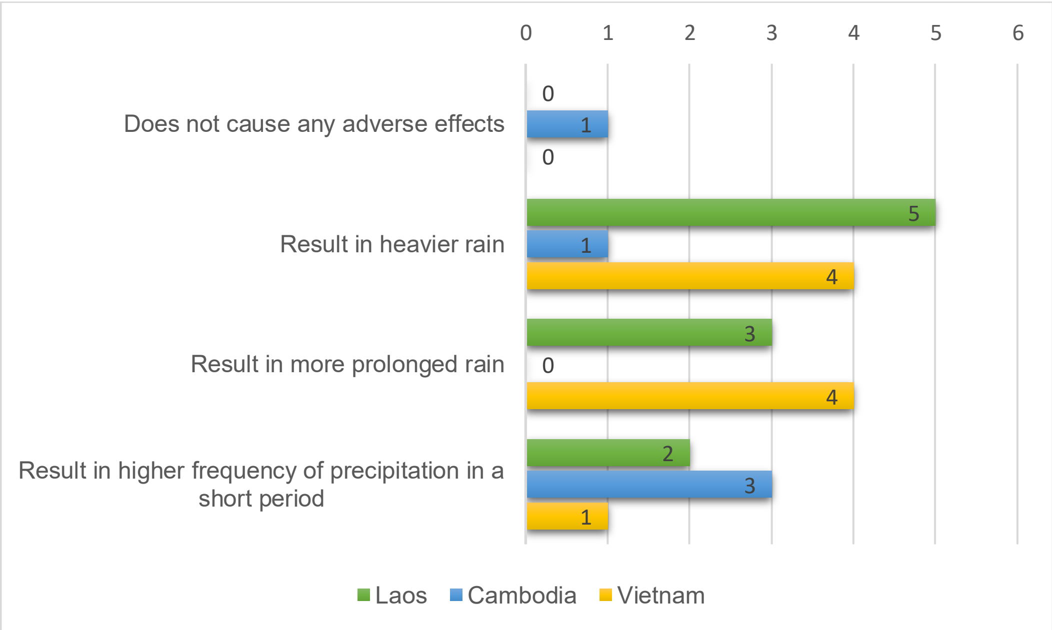


Figure 18: Effects of climate change on the weather.

All participants of Lao PDR and Cambodia felt agricultural production was the most affected by flooding while in Vietnam, 80% of respondents did. 80% of Laos and Vietnamese drivers/collectors also assumed that it can also suffer from drought.

While 100% of Laos and Vietnamese respondents agreed with the necessities of both collecting agricultural wastes for bio-fertilizer production and having the treatment facilities for agricultural wastes in their neighbourhood, less than half of Cambodian participants shared the same idea on these two activities (40% each).

The Figure below demonstrated the reasons why the survey participants wished to produce bio-organic fertilizers. Accordingly, the major reason was to serve the agricultural production (Lao PDR 4/5 vs Cambodia 3/5 vs Vietnam 3/5), then the soil quality improved by the bio-organic fertilizer (Lao PDR 4/5 vs Vietnam 3/5 vs Cambodia 1/5). Moreover, bio-organic fertilizer creation can help minimize environmental pollution which was caused by chemical fertilizers for the natural resources. Only 3/5 respondents from Lao PDR and 1/5 from Vietnam looked forward to saving cost from producing bio-organic fertilizers while no Cambodian drivers did.

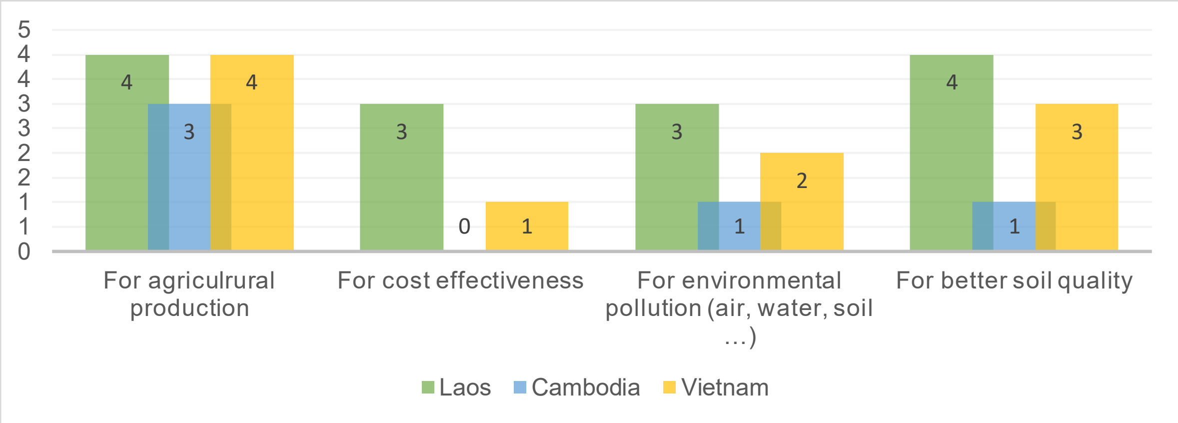


Figure 19: Effectiveness of producing bio-organic fertilizers.

In terms of the expected location of waste treatment facilities, in contrast to Cambodian drivers expecting the facilities to stay close to the houses and fields (40% and 60%, respectively), up to 60% of Lao PDR respondents wanted the facilities to be located far away from the community, the fields and the roads (including waterways) while only 20% pointed out the location should be in the downstream area, near the agricultural production area. The last suggestion was a clear, spacious area, in the treatment area, which should be allocated in an orderly manner. For Vietnam side, 4 out of 5 participants wished the facilities' position to be far away from the residential areas, the fields and water sources while 1 of them expected the location to stay inside the commune.

### 5.4.3 Desk study and in-depth interview with local authority staff and businesses in An Giang province

An Giang province is not only known as the province with the second highest rice output in Vietnam (after Kien Giang province) but also has favourable production conditions. Located at the headwaters of the Mekong River, supplied with fresh water all year round by the Tien and Hau rivers, virtually unaffected by sea level rise or saltwater intrusion, most of the province's rice land area is cultivable 3 crops/year. The total rice seeding area in the province is nearly 616,200 hectares; For vegetables, the planted area is nearly 49,600 hectares; For fruit trees, the current area is 19,700 hectares[1].

Currently, An Giang province has 05 centralized waste treatment areas, including: (1) Long Xuyen cluster solid waste treatment complex, Chau Thanh district: is operating sanitary landfill with a capacity of 245 tons/day and Investment in construction of a waste treatment plant (incineration technology), capacity of 300 tons/day, expected to be put into operation in 2025;

[1] *Department of Crop Production and Plant Protection, An Giang province*

(2) Canal 10 waste treatment area - City. Chau Doc is operating sanitary landfills, with a capacity of 200 tons/day; (3) Phu Thanh solid waste treatment area - Phu Tan district is currently operating sanitary landfill, with a capacity of 120 tons/day; (4) Thoai Son solid waste treatment plant (incineration technology), is operating stably, with a capacity of 50 tons/day; (5) Cho Moi solid waste treatment plant (incineration technology), treatment capacity of 100 tons/day, is installing an incinerator, expected to be put into operation in October 2023. In addition, there are currently 29 unhygienic landfills of household waste (currently stopped accepting garbage, causing environmental pollution). Currently, the Provincial People's Committee has assigned the Provincial Urban Development Area and Construction Investment Project Management Board to own the project of closing 28 landfills in the province, specifically the project of closing and treating household waste, Binh Hoa commune, Chau Thanh district is headed by Chau Thanh district People's Committee[2].

The in-depth interviews with local staff from the An Giang Department of Agriculture and Rural Development (DARD) and the Phu Tan District Agricultural sub-department have revealed that annual waste from agricultural production ranges from 500 to 700 tons in An Giang province. An Giang local authority has a policy to promote the production of agricultural waste into bio-organic fertilizer, but the scale is limited. An Giang DARD has implemented pilot models to encourage straw and by-product processing into fertilizer and bio-organic fertilizer. Some circular economy models addressing agricultural waste recycling have been implemented. At the Phu Tan district level, the model of processing waste into bio-organic fertilizer has not been applied; the district agricultural sub-department only promotes collecting pesticide shells after use by farmers to reduce agricultural waste without treatment of agricultural wastes. Currently, there is no large-scale factory in An Giang for bio-organic fertilizer production; small-scale facilities operate, with costs ranging from 20,000 to 25,000 VND/kg. Suggested locations for placing treatment plants in major production sub-regions aim to efficiently collect raw materials via waterway and land. Challenges in promoting bio-organic waste treatment in the province include processing time, raw material collection, seasonal variations, and low farmer adoption of organic fertilizer. An organic fertilizer production project has been initiated to enhance efficiency in An Giang province.

In An Giang province, locally generated agricultural solid waste is collected on-site by local people, stored, and sold to private organizations or reused for production. The remaining waste is then processed through burning or natural composting, following long-standing practices. Notably, the amount of pesticide packaging discharged into the environment

[2] *An Giang DoNRE*

(approximately 292–310 tons/year) was collected and processed during the period from 2018 to 2020, 24.38 tons[3] in total. These insights of the current state of agricultural waste management in An Giang province shows the need for targeted policies and infrastructure improvements.

### 5.4.4 In-depth interview with local private enterprise working related areas of bi-organic fertilizer production in An Giang province

An in-depth interview with Phu Thanh Agricultural Cooperative in An Giang province was conducted to understand the context and case study of an organic waste treatment company in Mekong region. Phu Thanh Agricultural Cooperative is a leading unit in the province's new cooperative development movement, providing practical benefits to its members and farmers. Established in 2005 through the merger of three cooperatives—Duc Loc, Phu Cuong, and Truong Thanh—Phu Thanh Agricultural Cooperative operates across a service area of 1,700 hectares, serving 1,750 production households and comprising over 154 members. The cooperative focuses on two main services: irrigation pumping and agricultural drying. It also provides input services and collaborates with enterprises that consume sticky rice products produced by its members and farmers throughout the entire commune.

Thanks to its diverse services, transparency in production and business operations, and an increasing number of participating members, Phu Thanh Agricultural Cooperative has improved its operational efficiency. By the end of 2023, the cooperative expanded its activities to include **agricultural waste treatment in bio-organic fertilizer**. The bio-organic fertilizer factory, situated near the cooperative on a 1.000m² land plot, has a capacity of 150 tons per year. The construction and equipment costs amount to 1.5 billion VND, with an annual operating cost of 300 million VND and transportation fees of 45 million VND. The factory generates annual revenue of 500 million VND. The cooperative's representative emphasizes that waste should not remain in the landfill for more than one month before being used in production to avoid adverse effects on the surrounding environment and the quality of organic fertilizer. Phu Thanh Agricultural Cooperative faces challenges related to environmental pollution and climate change, including rising temperatures, increased rainfall, and unusual weather conditions directly impacting rice and glutinous rice productivity and quality.

Currently, Phu Thanh Agriculture Cooperative receives support from local authorities to participate in the project called "1 million hectares of high-quality rice with low emissions." This

[3] *Announcement of current environmental status of An Giang province during 2016 – 2020.*

initiative implements the 1M6R-AWD (1 must, 6 reductions) model, contributing to greenhouse gas emissions reduction and promoting a circular economy in agricultural production. The Phu Thanh agricultural cooperative's model serves as a good practice for supporting sustainable agricultural waste management in the Mekong Delta region.

## 5.5 Discussion

### 5.5.1 Perceived agricultural wastes and climate change in the Mekong Delta

Survey results show that the primary agricultural wastes in the target areas are straw and manure. These wastes are generated from agricultural production without treatment to make bio-organic fertilizer. Many farmers have higher adoption rates for treating these agricultural wastes and converting them into bio-organic fertilizer in Lao PDR. However, most farmers in An Giang province, Vietnam are lack the adoption of bio-organic fertilizer production. Experiences in generating and storing bio-organic fertilizers have been noted among farmers in Cambodia and Lao PDR. Farmers have various options for collecting agricultural production wastes, but manual treatment and transportation vehicles are primarily used. The lack of transportation vehicles, difficulties, and insufficient waste treatment facilities as well as treatment organizations are key challenges for inadequate bio-organic fertilizer production from agricultural wastes. It is evident that the collection of agricultural wastes in the region is insufficient compared to the demand.

The assessment reveals that, according to farmers' opinions, the impacts of climate change on agricultural production and waste management are most acutely felt. The greatest impacts of climate change include heavier and prolonged rains leading to flooding in the region, as well as a higher frequency of rainfall in a short period of time. Consequently, flooding is considered one of the most serious problems caused by climate change for agricultural production in the region.

### 5.5.2 Social, economic and environmental impacts of climate change on agricultural production and waste management

The impacts of climate change on agricultural production, particularly flooding, have significant effects across economic, social, and environmental aspects. Among farmers and drivers in three countries, the main social impacts of flooding include 'deep floods impeding transportation,' while the primary economic impact is the 'reduction of farmers' productivity.' Ensuring efficient road maintenance during flood periods is therefore a priority for local people.

**Economic impacts:** Flooding damages crops, leading to reduced productivity and financial losses for both farmers and drivers. Income loss occurs due to reduced productivity and damage to crops. Additionally, time lost caring for children who are unable to attend school during floods further impacts income. Missed work due to flooding significantly affects both farmers and drivers. The most critical impact identified by respondents was decreased income, affecting agricultural productivity and crop damage.

**Environmental impacts:** Farmers and drivers are vulnerable to pollution exacerbated by floods. Garbage carried by floodwaters and wastewater impact local people. Environmental pollution leads to poor hygiene in local living environments and outbreaks of various epidemics. Pollution is considered the most critical environmental impact.

**Sustainable agriculture waste production:** Both farmers and drivers recognize the concept of climate change and its impact on agricultural production. Respondents believe that climate change contributes to wider, deeper, and more prolonged floods each year, affecting agricultural productivity and sustainability. Local farmer communities support production of bio-organic fertilizers from agricultural wastes. Initial manual production methods need further support and encouragement from local authorities to promote sustainable waste management and climate-resilient agricultural practices.
Overall, most interviewed farmers and drivers demonstrate satisfactory awareness of flooding, climate change, and perceived agricultural sustainability.

### 5.5.3 Needs and challenges in sustainable agricultural waste management

Collecting recyclable waste and converting it into organic fertilizer is a step in the right direction. This practice helps create microbial organic fertilizer for clean agriculture, contributing to solving environmental pollution issues caused by waste. An effective treatment measure, supported by interviewed people, involves recycling agricultural waste into organic fertilizer, thereby transforming it into raw materials suitable for clean agricultural practices. However, at present, waste from agricultural production has not been effectively collected and remains severely limited in terms of recycling into organic fertilizer products for agricultural use in the Mekong Delta region. (i) Distance and transportation difficulties, (ii) absence of agricultural waste collection organizations and inadequate agricultural waste treatment facilities are challenges for sustainable agricultural management.

Another significant pollution concern is the burning of crop residues such as straw and husks. Burning was widely practiced, including by rice, coffee, and maize farmers. According to one survey in Mekong delta (*Tran Sy Nam et al., 2014)*, up to 98 percent of surveyed farmers in the Mekong Delta burned straw after the winter-spring season, 90 percent burned it after the summer-autumn season, and 54 percent burned it after the autumn-winter season. Burning crop residues has been a common practice to eliminate wastes after harvesting because it is an inexpensive and quick way to prepare land for the next crop. Burning is also considered as the most popular solutions by Vietnam farmers from this survey. The burning of agricultural residues emits pollutants that pose a significant health hazard and may contribute to short-term climate warming. Burning of straw and husks are the key issues causing pollution from agricultural production in Mekong delta region. Solutions to reduce burning practices in agricultural production are foreseen to ensure sustainable agricultural production.

### 5.6 Recommendations

Addressing these impacts requires adaptive strategies and sustainable practices. Climate-smart agriculture and resilient infrastructure play crucial roles in mitigating the effects of flooding on agricultural systems. Solutions towards sustainable waste management at the Mekong Delta are recommended as the followings:

1. **Promote communication and awareness**: Increase communication and raise awareness about climate change and its impact on agricultural waste management, particularly flooding. Promote application of green agricultural production models.
2. **Raise awareness of farmers**: Educate farmers about the importance of ceasing the burning of crop residues, such as straw and husks, to reduce pollutant emissions; promote using green materials and products in agricultural production.
3. **Allocate budgets for impact assessments**: Government agencies should allocate budgets for socio-economic and environmental impact assessments related to agricultural waste management. These assessments will inform mitigation measures at the local level.
4. **Comprehensive flood mitigation measures**: Develop flood mitigation strategies that integrate both soft (community-based) and hard (infrastructure) components. These measures should align with socio-economic development planning and investment.
5. **Invest in climate-resilient waste management**: Invest in climate-resilient agricultural waste management, including waste treatment facilities and infrastructure.
6. **Community-based waste management**: Promote community-led waste management initiatives.
7. **Collaboration across sectors**: Encourage collaboration between governments, private sectors, and local communities to enhance agricultural waste management practices.

## 6. The Case Study

After doing online survey, qualitative and quantitative analysis, and studying the challenges for the sustainable agricultural waste management at the Mekong Delta, we developed a case study that can capture the realistic characteristics/issues for building the mathematical models and validate the performance of our models.

An Giang province is known as one of the Vietnam Mekong Delta's pioneer provinces in the development of organic fertilizer, mushroom and biomass energy production from agricultural waste. Sustainable agricultural waste management models play a critical role to enhance the efficiency of organic fertilizer, mushroom and biomass energy production network. An Giang's planners study solutions to seek such efficient and sustainable agricultural waste management models. The models need to ensure that agricultural waste from fields is fully collected, economically and reliably transported to the waste treatment facilities. Therefore, we constructed the case study at An Giang province for the implementation of sustainable agricultural waste management models to be developed.

In the case study, we consider 25 site candidates for locating organic fertilizer, mushroom and biomass energy production facilities from agricultural waste, 11 storages, and 145 waste collection points (i.e., fields). Here, the number of facilities is based on such operating facilities, the number of storages is based on the number of districts, and the number of waste collection points is based on the number of rice fields, at An Giang province. Figure 20 shows the locations of fields and facilities. A fleet of 5-ton trucks are used to serve the collection of agricultural waste from fields to storages and from storages to facilities. Distance matrices between fields and storages, and between storages and facilities are computed based on real road network. Disruption risk for road network is determined based on the water level of roads from food map. Figures 21 and 22 present two scenarios (by 2030 and by 2050, under the most extreme weather condition, i.e., the heavy rainfall and the sea level rising 33 cm) of the predicted flood maps for An Giang province, the Vietnam Mekong Delta.

For the data protection, we labelled 145 collection points by C1 – C145, 11 storages by S1 – S11, and 25 facilities by F1 – F25 (including FM1 – FM18, and FE1 – FE7 for mushroom and biomass energy production, respectively). Since the bio-organic fertilizer production from agricultural waste has not been deployed significantly at An Giang province (see the report in Section 5), we do not have much information of facility type, and thus do not consider in the case study. The data (e.g., demand of fields, distance matrices, flooded areas, etc.) for running mathematical models are provided in Appendixes E – G.

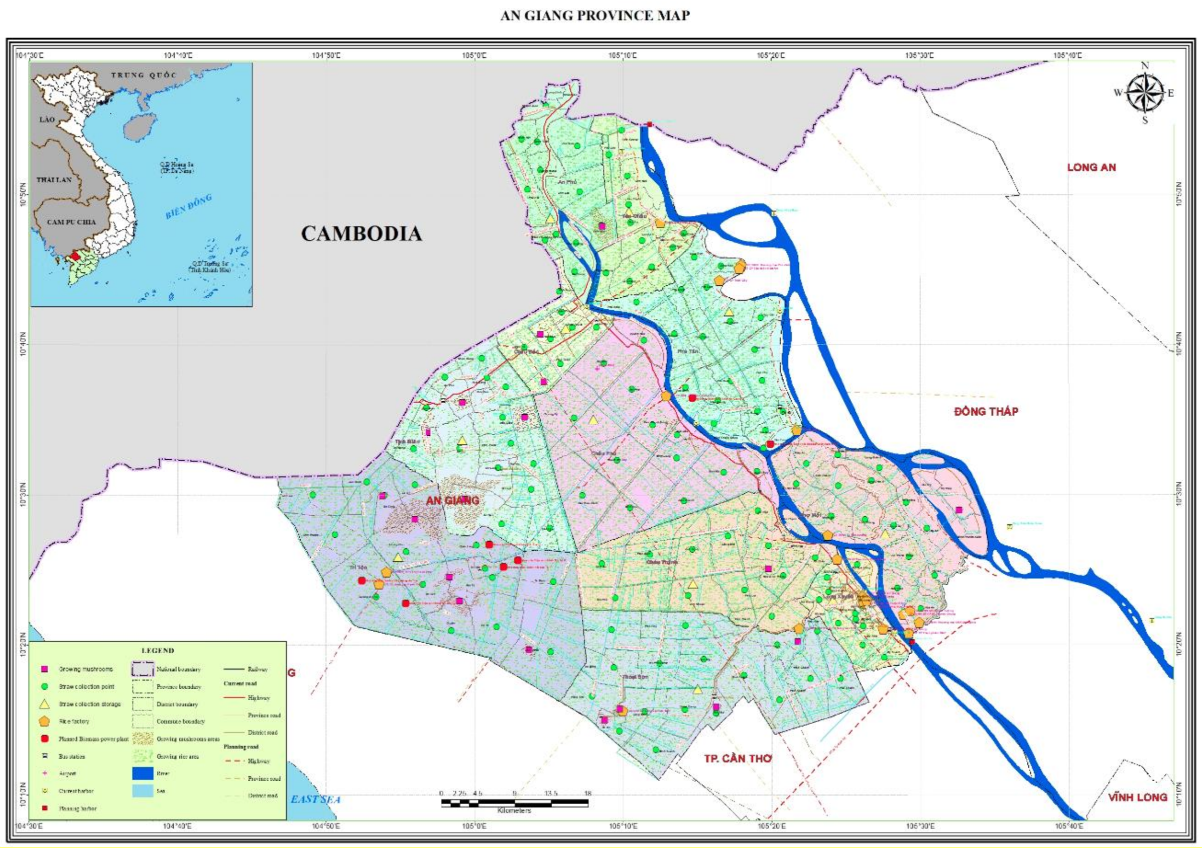


Figure 20: Map for fields and facilities in the case study.

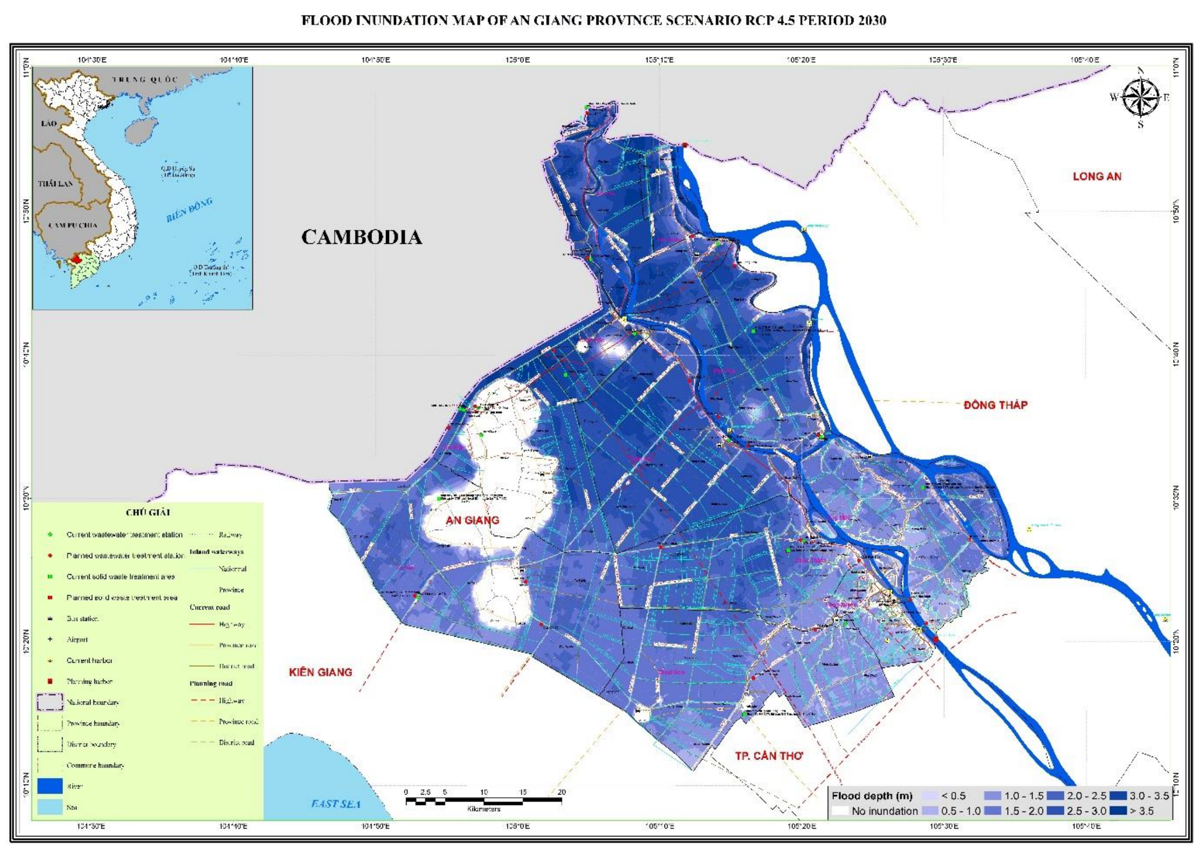


Figure 21: Flood map for the case study by 2030.

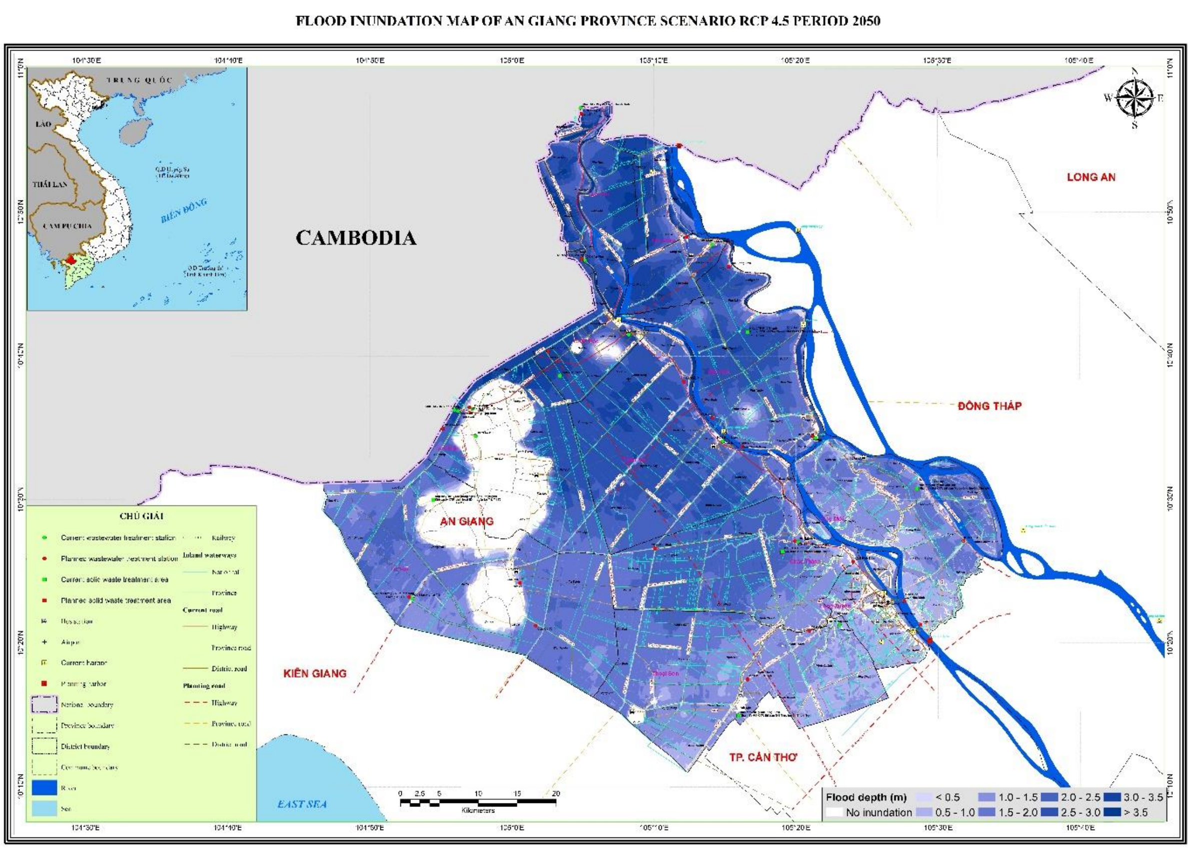


Figure 22: Flood map for the case study by 2050.

## 7. Mathematical Programming Models

For the case study at An Giang province, the Vietnam Mekong Delta, we developed a novel sustainable agricultural waste management model (SAWM) to stop burning the agricultural waste at fields and utilise the waste for organic fertilizer, mushroom and biomass energy production. In addition, we developed a strategic flood mitigation planning model to mitigate the impact of flood on the agricultural waste management at the Mekong Delta.

### 7.1. Problem statement

These two models are formulated as mixed-integer linear programming problems in which:

- **Decision variables:**
  - Which roads are selected for long-term investment to maximise the mitigation of flood impact on the agricultural waste management?
  - Where are the locations of storages?
  - Where are the locations of bio-organic fertilizer, mushroom and biomass energy production facilities?
  - Which fields are served by storages? Which storages are served by facilities?
- **Objective functions:**
  - Minimise total cost (including expected demand, travel distance, and disruption risk) of sustainable agricultural waste management network.
  - Minimise the impact of flood (disruption risk) on the sustainable agricultural waste management network.
- **Constraints and parameters:**
  - Total investment budget (e.g., maximum number of storages and facilities).
  - Candidates for storage and facility locations.
  - Flood maps, and disruption risks for locations and transport networks.

These adapted models are different from the previous models:

- Considering both road and river networks.
- Considering multiple locations of agricultural waste treatment facilities.
- Considering the impact of flood (disruption risk) on transport network, and storage and facility locations.

Novel parameters of the adapted models help to address the realistic characteristics of the Mekong Delta and provide the practical solutions.

The mathematical model for flood mitigation problem on transport network can be referred to Phouratsamay et al. (2024), while the mathematical model for agricultural waste collection and transport network design can be referred to Tran et al. (2023).

These models have been coded and implemented in C++ with IBM ILOG CPLEX callable libraries. We run separately two optimisation models in which the FMP is solved first to seek the critical infrastructure to plan protection to minimise the impact of flood impact on the SAWM, and then the SAWM is solved with the constraints of (protected) road and river networks to minimise total cost of agricultural waste collection, transport, and treatment network design.

### 7.2. Nove reliable storage-and-facility location model

When solving the case study, we recognised that the capacity of storages is large, so vehicle routing problem could not be necessary. We thus developed a novel mathematical model in which vehicles can collect agricultural waste and transport directly from storages to facilities (that is correct with the realistic condition at the Mekong Delta). Table 16 shows the mathematical notations for this new model, and Table 17 shows the mathematical formulation.

Table 16: Mathematical notations.

| Notation | Description |
|---|---|
| Sets and indexes: | |
| $I$ | Set of agricultural waste fields (indexed by $i$) |
| $J$ | Set of storages (indexed by $j$) |
| $K$ | Set of facilities (indexed by $k$) |
| $i_s, i_\ell$ | Denote the $s$th, $\ell$th closest storage to field $i$ |
| $j_t, j_\ell$ | Denote the $t$th, $\ell$th closest facility to storage $j$ |
| $\bar{i}_j$ | Denote the closest rank (th) of storage $j$ to field $i$ |
| Parameters: | |
| $m$ | Number of storages (i.e., $m = \|J\|$) |
| $n$ | Number of facilities (i.e., $n = \|K\|$) |
| $h_i, h_j$ | Amount of agricultural waste collected at field $i$, storgae $j$ |
| $d_{ij}, d_{jk}$ | Travel cost (or distance) between field $i$ and storage $j$, between storage $j$ and facility $k$ |
| $r_{ij}, r_{jk}$ | Risk of disruption (due to flooding) on link $(i,j)$, link $(j,k)$ |
| $q_j, q_k$ | Failure probability at storage $j$, facility $k$ |
| $\overline{q}_j, \overline{q}_k$ | Successful probability at storage $j$, facility $k$ (i.e., $\overline{q}_j = 1 - q_j$, $\overline{q}_k = 1 - q_k$) |
| $\phi_1, \phi_2$ | Penalty cost for all storages failed, all facilities failed |
| $p_1, p_2$ | Number of openned storages, number of openned facilities |
| Decision variables: | |
| $X_j = \begin{cases} 1 & \text{if a storage is located at site } j \in J \\ 0 & \text{otherwise} \end{cases}$ | |
| $Y_k = \begin{cases} 1 & \text{if a facility is located at site } k \in K \\ 0 & \text{otherwise} \end{cases}$ | |

Table 17: Mathematical formulation.

$$\begin{aligned} \min \quad & \textstyle\sum_{i\in I} h_i \left(\sum_{s\leq m} d_{ii_s} r_{ii_s} \prod_{\ell<s} \left(1-\overline{q}_{i_\ell} X_{i_\ell}\right) \overline{q}_{i_s} X_{i_s} + \phi_1 \prod_{\ell\leq m} \left(1-\overline{q}_{i_\ell} X_{i_\ell}\right)\right) \\ & + \textstyle\sum_{j\in J} h_j \left(\sum_{t\leq n} d_{jj_t} r_{jj_t} \prod_{\ell<t} \left(1-\overline{q}_{j_\ell} Y_{j_\ell}\right) \overline{q}_{j_t} Y_{j_t} + \phi_2 \prod_{\ell\leq n} \left(1-\overline{q}_{j_\ell} Y_{j_\ell}\right)\right) \end{aligned} \tag{1}$$

$$\text{s.t.: } h_j = \sum_{i\in I} h_i \left( \prod_{\ell\leq \bar{i}_j} \left(1-\overline{q}_{i_\ell} X_{i_\ell}\right) \overline{q}_j X_j \right), \ \forall j \in J, \tag{2}$$

$$\sum_{j\in J} X_j = p_1, \tag{3}$$

$$\sum_{k\in K} Y_k = p_2, \tag{4}$$

$$X_j \in \{0,1\}, \ \forall j \in J, \tag{5}$$

$$Y_k \in \{0,1\}, \ \forall k \in K. \tag{6}$$

in which the objective function (1) is to minimise the total cost of expected demand weighted distance disruption risk between a set of demand points/fields (or storages) and their closest operational storages (or facilities). Constraints (2) are to compute the expected demand at each storage. Constraints (3) and (4) are the number of storages and facilities allowed to open (due to the budget limit). Constraints (5) and (6) are binary variables.

This model can support planners to design a novel sustainable agricultural waste collection and transport network that minimise disruption risks by flood impact on transport network and storage and facilities locations. Figures 23 and 24 show the current solution (i.e., agricultural waste is transported directly from fields to facilities, that has been deployed at the Mekong Delta) and our innovative solution (i.e., locating storages to collect agricultural waste from fields before transporting to facilities), and we also derived the condition to achieve the innovative solution (i.e., more reliable storage and facility locations), see Figure 25:

$$d_{ik_1} r_{ik_1} \geq d_{ij} r_{ij} + d_{jk_1} r_{jk_1}$$

We applied “probability chains” and “piecewise linear” techniques (see O’Hanley et al., 2013, and Tran and Ng, 2017, respectively) for linearize the mixed-integer non-linear programming model (in Table 17) into a linear form that can be solved by any optimisation solver (e.g., CPLEX, or GUROBI). Then, these models are described as the leader-and-follower problem:

[RSFLP-Leader]:

$$\min \ \textstyle\sum_{i\in I} h_i \left(\sum_{s\leq m} d_{ii_s} r_{ii_s} \prod_{\ell<s} \left(1-\overline{q}_{i_\ell} X_{i_\ell}\right) \overline{q}_{i_s} X_{i_s} + \phi_1 \prod_{\ell\leq m} \left(1-\overline{q}_{i_\ell} X_{i_\ell}\right)\right) \tag{7}$$

$$\text{s.t.: } \sum_{j\in J} X_j = p_1, \tag{8}$$

$$X_j \in \{0,1\}, \ \forall j \in J. \tag{9}$$

[RSFLP-Follower]:

$$\min \sum_{j\in J: X_j=1} h_j \left(\sum_{t\le n} d_{jj_t} r_{jj_t} \prod_{\ell<t} \left(1-\bar{q}_{j_\ell} Y_{j_\ell}\right) \bar{q}_{j_t} Y_{j_t} + \phi_2 \prod_{\ell\le n} \left(1-\bar{q}_{j_\ell} Y_{j_\ell}\right)\right) \tag{10}$$

$$\text{s.t.: } h_j = \sum_{i\in I} h_i \left(\prod_{\ell\le \bar{i}_j} \left(1-\bar{q}_{i_\ell} X_{i_\ell}\right) \bar{q}_j X_j\right), \ \forall j\in J: X_j = 1, \tag{11}$$

$$\sum_{k\in K} Y_k = p_2, \tag{12}$$

$$Y_k \in \{0,1\}, \ \forall k \in K. \tag{13}$$

When solving the case study by the new models, our solution can reduce approximately 30% total disruption risks for the agricultural waste collection and transport network at An Giang province. This solution will support policy makers to develop the sustainable agricultural waste management model under impact of climate change (i.e., flooding) at An Giang province, which lead to stop burning agricultural waste, and utilise efficiently the waste for bio-organic fertilizer, mushroom, and biomass energy production.

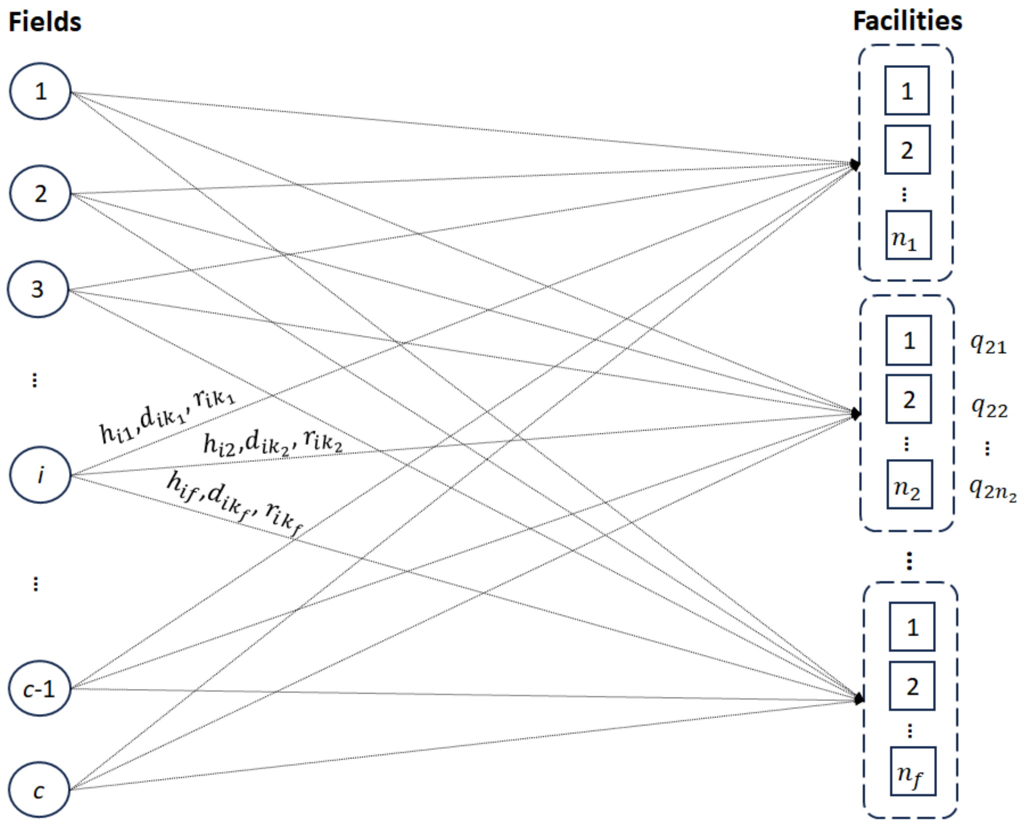


Figure 23: A hypothetical representation of the current solution.

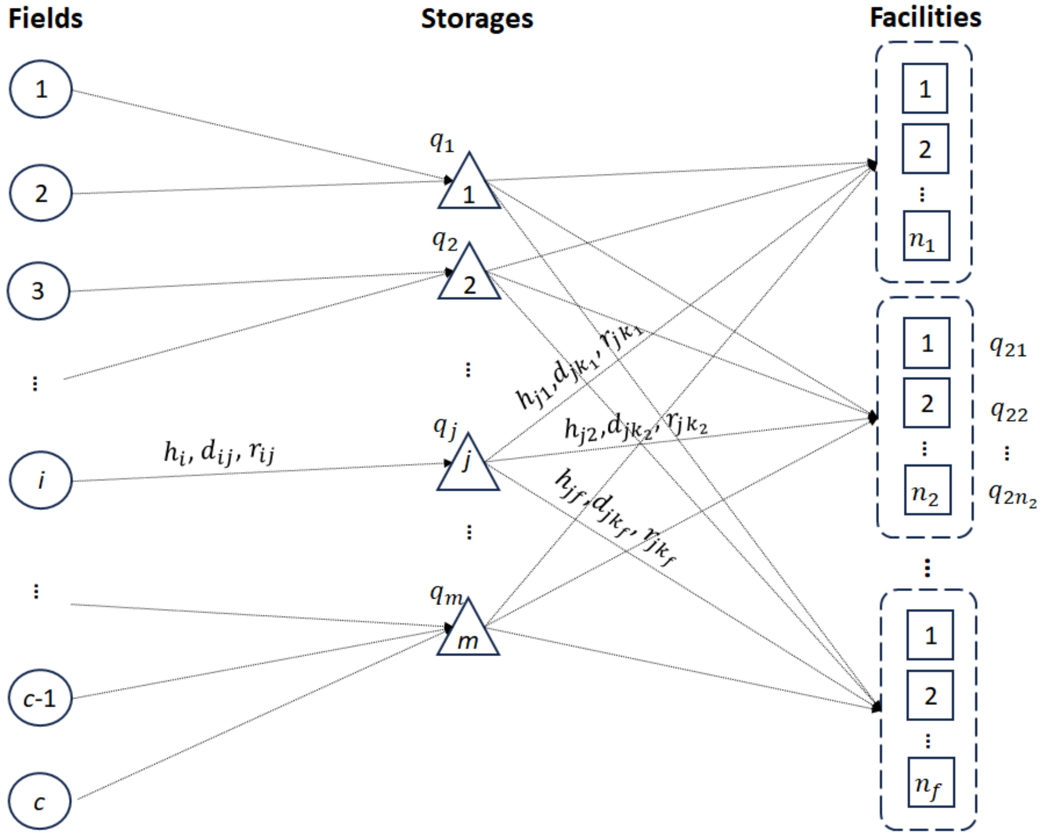


Figure 24: A hypothetical representation of the innovative solution.

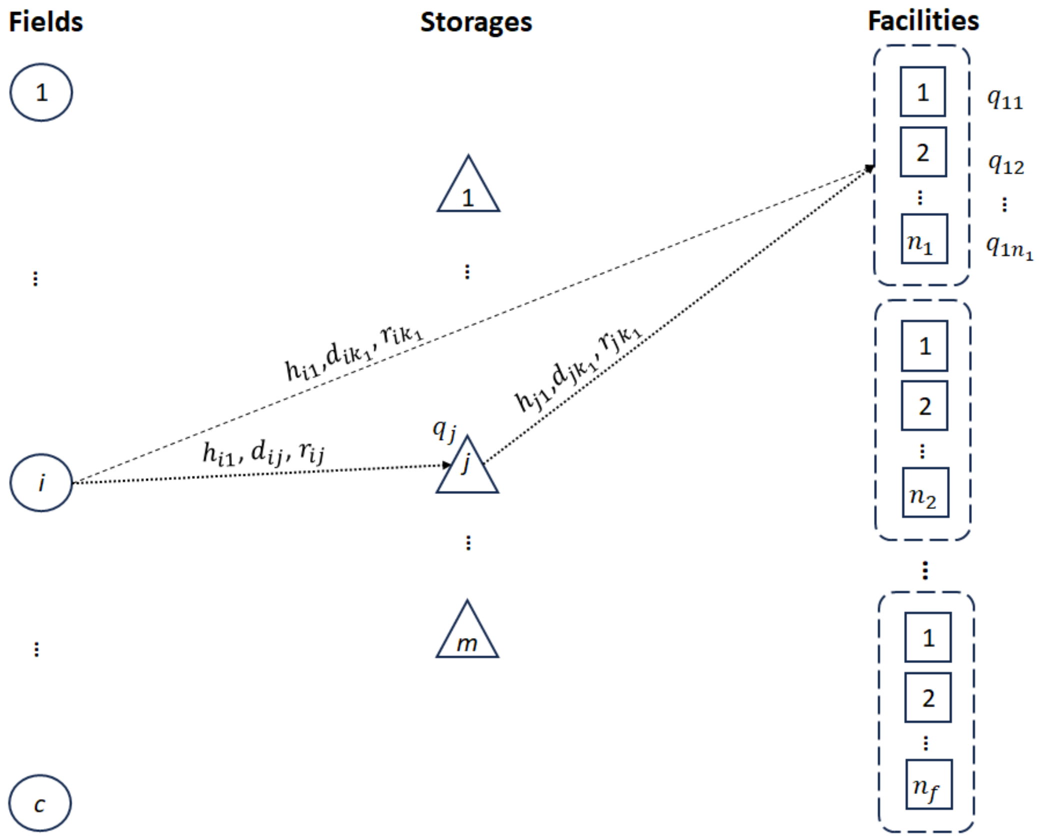


Figure 25: A hypothetical representation of the condition to achieve the innovative solution.

Our innovative solution is to locate 11 storages (large capacity) at 11 districts of An Giang province (i.e., Long Xuyên, Châu Đốc, An Phú, Tân Châu, Phú Tân, Châu Phú, Tịnh Biên, Tri Tôn, Chợ Mới, Châu Thành, Thoại Sơn), see yellow triangles in Figure 26, to collect agricultural waste from 145 fields and transport to 25 facilities. In the case that one of storages fails due to flooding, other storages can support to collect and store agricultural waste from fields. The model also determines the order of storages used to serve fields and the order of facilities used to serve storages (see Appendix H). It can be adapted to solve the sustainable agricultural waste management problem that consider different types of wastes, and types of treatment facilities.

The novel model has been coded and implemented in C++ with IBM ILOG CPLEX callable libraries. However, to run the model, we need to pre-process input data (from flood maps to disruption risks). Hence, it is essential to develop a Graphical User Interface (in which the data pre-processing is integrated) to support local planners to use it.

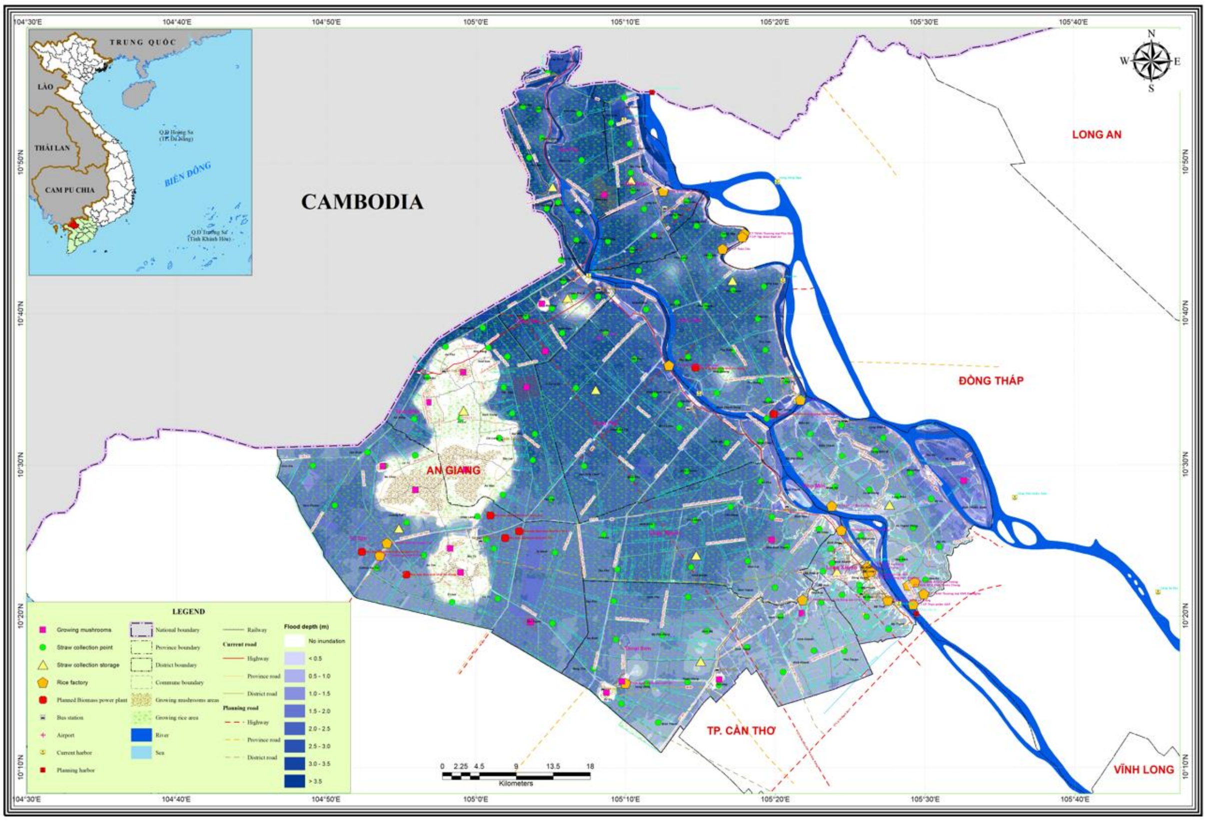

Figure 26: Our innovative solution for the case study at An Giang province.

## 8. Discussions

This project focused on the low-income and vulnerable ASEAN communities as key beneficiaries (KBs):

- KB1: Famers affected by burning agricultural waste.
- KB2: Drivers for waste collection.
- KB3: Workers at agricultural waste treatment facilities.
- KB4: Employees at fertilizer, mushroom and biomass energy production facilities.
- KB5: Street vendors affected by urban flooding.
- KB6: Local citizens.

The success of this project can improve the health (i.e., reducing the respiratory issues) and welfare (i.e., increasing the earnings and savings) of farmers, street vendors, local citizens, drivers, workers, and employees at the production facilities who directly work in agricultural waste management in the Mekong Delta. Many female farmers, male drivers and female workers/employees can receive benefits from this project such as increasing the employment rate and the economic growth. Furthermore, the quality of air and water will be improved as burning agricultural waste is stopped (i.e., reducing approximately 17.95 million tons of CO2, 485.58 thousand tons of CO and 10.38 thousand tons of NOx into the atmosphere), and the supply and price of bio-organic fertilizer meet the demand of farmers. In addition, the planning model for flood impact mitigation at the Mekong Delta can reduce traffic congestion to enhance the economic development of the delta.

This project can affect the relations between people of different genders and people of the same gender by attracting male workers from cities to come back to work in facilities that produce bio-organic fertilizer, mushroom and biomass energy from agricultural waste. Although it does not make much role change, balance of responsibilities in households can be achievable. The male workers working at near-home facilities could share the household responsibilities with female, e.g., caring of children, elderly, etc. Reducing burden of household responsibilities on female can leverage the gender inequalities in society and economy. Earnings and savings of female (i.e., increasing VND 10 million per month) can be improved when they have more job opportunities at the agricultural waste treatment facilities.

The optimisation models can be extended and adapted for other ASEAN countries (with the similar characteristics/conditions) towards a sustainable agricultural waste management. The sustainable agricultural waste management model could also enhance the supply chain development of bio-organic fertilizer and products at ASEAN countries, which leads to the impact mitigation of climate change on agriculture and aquaculture production at the region.

## 9. Project Limitations and Potential Next Steps

**Limitations:**

Due to the limit of project budget, we used online survey to collect the ideas of farmers and drivers on the agricultural waste management at the Mekong Delta (including Laos, Cambodia and Vietnam) and some other sustainability issues. However, it is challenged to get the large number of responses from farmers and drivers by online survey since they do not usually use internet. There are only 50 farmers and 5 drivers for the survey. In addition, the number of interviews is also limited.

The case study focused on only An Giang province, the Vietnam Mekong Delta. Hence, the model could get challenge to apply for other provinces at Laos and Cambodia in which the realistic conditions for implementing the sustainable agricultural waste management are different. In addition, it is a challenge to apply the model for all the provinces at **the Vietnam Mekong Delta** (i.e., multiple provinces – large scale practice), and for **the whole Mekong Delta** including Vietnam, Laos, Cambodia, etc. (i.e., different national policies of agricultural waste management).

Finally, the model did not consider **the impact of salinity intrusion** on sustainable agricultural production and waste management, while this is an essential issue caused by climate change.

**Final workshop:**

The final workshop, held on 4 September 2024 in Ho Chi Minh city- Vietnam, was a significant dissemination event that brought together 24 delegates, including 9 women, from various research units, universities, and local government bodies at Bong Sen Hotel Sai Gon (117 – 123 Dong Khoi, District 1, Ho Chi Minh City) and through teleconferencing with 10 virtual participants. The attendees included the research team, representatives from Ho Chi Minh City-based research units and universities, interested international partners and officials from An Giang local government and university (see Figure 27).

The workshop commenced with an opening remark by Dr. Tran Trung Hieu, the Principal Investigator from Cranfield University. Dr. Tran highlighted the objectives of the research and the collaborative efforts involved.

The results of the five work packages were presented by:

- Ms. Be Thi Hoang Yen from AMDI – WP 1&2

- Mr. Phung Duc Chinh from IMHEN – WP 3
- Dr. Thu Ba T. Nguyen from the University of Bedfordshire – WP 4&5
- Dr. Tran Trung Hieu from Cranfield University – WP 4&5

Each presenter provided detailed insights into their respective work packages, showcasing the progress and findings of the research.

Following the presentations, a Q&A session was held, allowing delegates to provide valuable feedbacks. Notable contributions came from Mr. Dang Thanh Phong, Vice Head of the Sub-Department of Plant Protection, An Giang DARD. Mr. Phong shared insights on agricultural production and the handling of agricultural by-products in An Giang province. He showed his support and interested in the OR model for sustainable agricultural waste management. He emphasized the need to integrate soil nutrient maps into flood maps to use straws and fertilizers sustainably. He also recommended involving cooperatives as storage locations for straws from rice production and expressed hope that the proposed model could be piloted in An Giang to address issues related to agricultural by-product collection, transportation, and production into bio-organic fertilizers.

Researchers from various universities and research institutions *(University of Technology, VNU HCMC; Ho Chi Minh University of Natural Resources and Environment; Van Lang University; Southern Institute of Water Resources Research; Sub-institute of Hydrometeorology and Climate Change; Mekong River Commission Secretariat to Vietnam)* expressed their interest in the OR model. They shared their knowledge and experience on the actual research situation in the Mekong Delta region with the research team.

The workshop also discussed future research opportunities to expand the research scope in other areas. Dr. Nguyen shared potential opportunities for future research funding and discussed her planned research in Indonesia, focusing on optimizing aquaculture production using OR models. Dr. Tran shared some funding opportunities that could be applied for future cooperation with interested research partners in Vietnam.

Dr. Tran concluded the workshop by encouraging researchers and stakeholders to share similar proposals for future cooperation. He acknowledged the challenges faced during the research, such as budget constraints, limited scope and time, and restricted access to local businesses. Despite these challenges, the team achieved certain outputs to support raising awareness on sustainable agriculture production and proposed an optimization model for agriculture production planning.

The workshop was a productive and insightful event, fostering collaboration and setting the stage for future research endeavors.

Figure 27: Photo for the final workshop at Ho Chi Minh city, Vietnam on 4th Sep 2024.

**Next steps:**

After the period of this project, we will transfer the knowledge (models and findings) to An Giang Provincial Department of Agriculture and Rural Development, and Mekong River Commission Secretariat (the stakeholders who will be invited to attend the final workshop) to continue monitor the project development impact.

In addition, we will continue to seek GCRF funds (from FCDO RIDA Phase 2, British Council, and British Academy) to extend and adapt the sustainable agricultural waste management model for all the provinces in the Vietnam Mekong Delta, as well as the whole Mekong Delta (covering Vietnam, Laos, Cambodia, and Thailand).

The on-going projects will also consider the following academic issues:

- ❖ To complete the model under impact of salinity intrusion
- ❖ To develop an efficient meta-heuristic algorithm for solving large-scale instances.

To address the challenges of implementing further the model for all the provinces at **the Vietnam Mekong Delta** and for **the whole Mekong Delta** including Vietnam, Laos, Cambodia, etc., we need to do **more on-site survey and interviews with the large number of participants (app. one thousand)** covering all the provinces at the Mekong Delta (including Vietnam, Laos and Cambodia) to understand the realistic specific needs and challenges at each province. In addition, we need to **collect more data to generate high-resolution (10x10 meters) maps for both flood and salinity intrusion impact on sites and roads**. We also need **to recruit a Research Assistant (with the expertise in software engineering)** to support **coding the meta-heuristic algorithm (under Dr Tran's supervision)** for solving the large-scale multi-province instances and **designing Graphical User Interface to help planners (without the knowledge of Operational Research)** easily to use the model and algorithm in the future. Finally, we need to **involve policy makers from ASEAN countries on sustainable agricultural production and waste management and high-level executives (e.g., Ministry of Agricultural and Rural Development)** to consider totally different (now and future) national policies of agricultural production and waste management into modelling innovative solutions, which leads to effective practice implementation for long-term goals.

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## APPENDIX

### Appendix A: Survey (beginning page)

**Research Project:**
**An intergrated decision support system for Strategic Flood mitigation planning towards sustainable agricultural waste mangement at the Mekong Delta (IDSS-MEKONG)**

**Opening**

We invite you to participate in a survey of IDSS-Mekong on impact of climate change on agricultural production and waste management at Mekong Delta. Your answers will help us create a plan to research on developing an integrated support tool for strategic flood mitigation and waste management planning in Mekong delta region.

Your answers are private and will only be used for research purposes.

**CODING**

**GENERAL INFORMATION**



| NO. | QUESTIONS | ANSWER CHOICES | Answer code | |
|---|---|---|---|---|
| 1 | Where are you from? | Vietnam | A | |
| | | Laos | B | |
| | | Cambodia | C | |
| 2 | Your gender | Male | A | |
| | | Female | B | |
| | | Others | C | |
| 3 | Your age | …….. | A | |
| 4 | Your career | Farmers | A | go to questionaires for farmer |
| | | Drivers for waste treatment facilities | B | go to questionaires for Driver |
| | | Local government staff of An Giang province, Vietnam only | C | go to questionaires for local government staff |

**Appendix B: Survey for famers**

**Research Project:**

**An integrated decision support system for Strategic Flood mitigation planning towards sustainable agricultural waste management at the Mekong Delta (IDSS-MEKONG)**

**Questionnaires for Farmers**

**CODING**

**Agricultural waste production**

| NO. | QUESTIONS | ANSWER CHOICES | Answer code |
|---|---|---|---|
| 1 | What is the area of your agricultural land? | | A |
| 2 | Do you use organic fertilizer for agricultural production? If yes, How much do you use per year? | No | 0 |
| | | Yes | 1 |
| | | Specify: …. Tons | Z |
| 3 | Types of waste are generated from your agricultural production? | Straw | A |
| | | Duckweed | B |
| | | Manure | C |
| | | Other scraps, by-products: | Z |
| 4 | Do you use these wastes to produce bio-organic fertilizer for agricultural production? | No | 0 |
| | | Yes | 1 |

| | | | | |
|---|---|---|---|---|
| 5 | If yes, How many times per year do you collect agricultural wastes for bio-organic fertilizer? | ….. | Times | Z |
| | If yes, How much is the volume of agricultural waste (tons) collected approximately? | …. | Tons | Z |
| | If yes, How long can you store agricultural waste? | … | Months | Z |
| | If yes, Distance from the collected areas to composting place? (approximately) | … | km | Z |
| | If yes, How much do you have to pay for agricultural wates collection per year? (wage, transportation cost, collection, storage …?) (approximately) | … | VND mill | Z |
| 6 | If no, who will collect these agricultural wastes? | Local cooperatives | | A |
| | | Private enterprises | | B |
| | | Other households | | C |
| | | Others | Specific : ……. | Z |

| | | | | | |
|---|---|---|---|---|---|
| 7 | Selling price | …. | VND | per tons | Z |
| 8 | Types of vehicles for agricultural waste transportation? | Bullock cart | | | A |
| | | Wheelbarrow | | | B |
| | | Small farm vehicle | | | C |
| | | Car | | | D |
| | | Others | Specific : | ……. | Z |
| 9 | Difficulties in collecting or producing bio-organic fertilizers from agricultural wastes? (Multiple choices possible) | Lack of collecting vehicles | | | A |
| | | Long distance and difficulty in transportation | | | B |
| | | Lack of labour | | | C |
| | | Lack of storage | | | D |
| | | Lack of agricultural waste treatment facilities | | | E |
| | | Lack of agricultural waste collection organizations | | | F |
| | | Others | Specific : | ……. | Z |
| **CLIMATE CHANGE AND IMPACTS ON AGRICULTURAL PRODUCTION** | | | | | |
| 10 | Have you ever heard of climate change? | No | | | 0 |
| | | Yes | | | 1 |
| 11 | | Does not cause any adverse effects | | | A |

| | | | |
|---|---|---|---|
| | In your opinion, how does climate change affect the precipitation? (Multiple choices possible) | Result in heavier rain | B |
| | | Result in more prolonged rain | C |
| | | Result in higher frequency of precipitation in a short period | D |
| | | Other, specify: | Z |
| 12 | Is your agricultural production impacted by climate change | No | 0 |
| | | Yes | 1 |
| 13 | If yes, which cause impacts? | Flooding | A |
| | | Drought | B |
| | | Soil salinity | C |
| | | Others Specific …….: | Z |
| **ASSESSMENT OF ECONOMIC IMPACTS CAUSED BY FLOOD** | | | |
| 14 | What are the flooding impacts on your agricultural production? (Multiple choices possible) | Damaged plants | A |
| | | Reduced productivity | B |
| | | Sharply increasement of pests and diseases | C |
| | | Others Specific …….: | Z |
| 15 | When was last experience of flooding in your agricultural production? | This year | A |
| | | 1 year ago | B |
| | | 2-3 recent years | C |
| | | More than 3 years ago | D |

| | | | | |
|---|---|---|---|---|
| | | Others | Specific .......: | Z |
| 16 | How deep is your production field flooded in water? | Below 0.2 m | | A |
| | | From 0.3 to 0.5 m | | B |
| | | From 0.5 to 1 m | | C |
| | | Above 1 m | | D |
| | | Others | Specific .......: | Z |
| 17 | How much is the estimated cost of damages after last year floods? | .... | VND mill | |
| 18 | Does your household purchase agricultural production insurance? | No | | 0 |
| | | Yes | | 1 |
| 19 | How does the flood impact on your family's income? (Multiple choices possible) | Cannot plant on the field for a long time | | A |
| | | Cannot harvest on time | | B |
| | | Reduced quality and devaluation | | C |
| | | Others | Specific .......: | Z |
| 20 | If you cannot go to the field for planting due to flood, how many days do you have to be off from work? | .... | days | |
| 22 | | Completely serious | | 1 |

| | | | |
|---|---|---|---|
| | How will you rank importance of economic impacts of flooding to your agricultural production? | Seriously | 2 |
| | | Neutral | 3 |
| | | Slightly | 4 |
| | | Barely | 5 |
| **ASSESSMENT OF THE ENVIRONMENTAL IMPACTS CAUSED BY FLOOD** | | | |
| 23 | In flooding season, how long does it often last? | Less than 1 day | A |
| | | 1 day | B |
| | | 2-3 days | C |
| | | 4 - 7 days | D |
| | | Over 1 week | E |
| | | Other, specify: | Z |
| 24 | When flooding occurs, what are the factors that cause pollution in your residence? | Solid wastes | A |
| | | Waste water | B |
| | | Carcases | C |
| | | Other, specify: | Z |
| 25 | Does stretch appear after prolonged downpour? | No | 0 |
| | | Yes | 1 |
| 26 | Where does the overpowering stench origin from? | Overflow of polluting rivers/arroyos/reservoirs/canals | A |
| | | Wastes | B |
| | | Other, specify: | Z |
| 27 | What are the impacts of environmental pollution? | Resulting in the gradual death for green trees | A |
| | | Poor hygiene of the local living environment | B |

| | | | |
|---|---|---|---|
| | | Facilitating the outbreak of various epidemics | C |
| | | Poor health and increased costs of health treatment | |
| | | Other, specify: | Z |
| 28 | Which are the common diseases during the flooding period (during and after)? | Skin diseases (athlete's foot, scabies, impetigo, etc.) | A |
| | | Pinkeye | B |
| | | Dengue | C |
| | | Diarrhoea | D |
| | | Respiratory diseases (sore throat, flu, bronchitis, etc.) | E |
| | | Other, specify: | Z |
| | | **ASSESSMENT OF SOCIAL IMPACTS** | |
| 29 | How does flood impact on transportation? | No obstructions | A |
| | | Deep flooding water impeding the transportation | B |
| | | Difficult transportation, traffic jam in many hours | C |
| | | Other, specify: | Z |
| 30 | Can your children go to school? | No | 0 |
| | | Yes | 1 |
| 31 | If no, during each flood season, how many days do children have to be absent on average? | 1 day | A |
| | | 2 days | B |
| | | 3 - 5 days | C |
| | | 1 week | D |
| | | Over 1 week | E |
| | | Other, specify: | Z |

| | | | |
|---|---|---|---|
| 32 | Does your family experience any difficulties in approaching the healthcare stations during the flooding time? | No | 0 |
| | | Yes | 1 |
| 33 | Are there any difficulties in approaching public services in your residence? (Multiple choices possible) | Ward/district administrative procedures | A |
| | | Postal services | B |
| | | Cultural services | C |
| | | Other, specify: | Z |
| 35 | How will you rank importance of social impacts of flooding? (Multiple choices possible) | Prolonged traffic congestion at severely flooded hotspots | A |
| | | Children's absence from schools | B |
| | | Difficulty in access to healthcare services | C |
| | | Difficulty in access to other public services (administrative procedure, security, postal services, etc) | D |
| | | Weaker community cohesion | E |
| | | Difficulty in transportation including transportation of the agricultural products and wastes | F |
| 36 | Did you meet difficulty in transporting agricultural waste to treatment facilities? | No | 0 |
| | | Yes | 1 |
| **Solution** | | | |
| 37 | | No | 0 |

| | | | |
|---|---|---|---|
| | Do you think that collection of agricultural wastes for bio-organic fertilizer is necessary? | Yes | 1 |
| 38 | Is this necessary to have the waste treatment facilities in the region for agricultural waste treatment? | No | 0 |
| | | Yes | 1 |
| 39 | Why do you prefer to produce bio-organic fertilizers? (Multiple choices possible) | For agricultural production | A |
| | | For cost effectiveness | B |
| | | For environmental pollution (air, water, soil …) | C |
| | | For better soil quality | D |
| | | Others Specific : ……. | Z |
| 40 | According to your opinion, where should the waste treatment facilities located? | ……... | Z |

**Appendix C: Survey for drivers**

**Research Project:**

**An integrated decision support system for Strategic Flood mitigation planning towards sustainable agricultural waste management at the Mekong Delta (IDSS-MEKONG)**

**Questionnaires for Drivers for Waste collection**

| NO. | QUESTIONS | ANSWER CHOICES | | Answer code |
|---|---|---|---|---|
| 1 | On average, how many tons of waste do you collect per day? | …... | Tons | A |
| 2 | Means of transport to collect waste? | Garage Truck | | A |
| | | Manual Dustcart | | B |
| | | Others | Specific : ……. | Z |
| 3 | Do you collect agricultural waste? (Agricultural waste includes straw, duckweed, livestock and poultry manure, other agricultural waste...) | No | | 0 |
| | | Yes | | 1 |
| 4 | Is waste sorted for recycling? | No | | A |
| | | Yes | | B |
| | | Partly | | C |
| 5 | Where will you transport waste to? | Landfill | | A |

| | | | | |
|---|---|---|---|---|
| | | Dumping site with treatment factory | | B |
| | | Waste treatment for bio-organic fertilizer | | C |
| | | Others | Specific : ……. | Z |
| 6 | How far is this from the waste collection area to the waste treatment place? | …. | km | 0 |
| 7 | Do you encounter any difficulties while collecting waste under flooded conditions? (Multiple choices possible) | Vehicle breakdown/engine stalling due to driving through deep water level | | A |
| | | Prolonged traffic congestion and congestion due to flooding | | B |
| | | Vehicles move slowly or stop temporarily, stuck in deeply flooded streets | | C |
| | | Others | Specific : ……. | Z |
| 8 | Do you know any agricultural waste treatment areas in the area? | No | | A |
| | | Yes | | B |
| 9 | Are the areas where you regularly collect trash flooded? | No | | A |
| | | Yes | | B |
| 10 | How deep is your collection area flooded in water?? (approximately) | Below 0.2 m | | A |
| | | From 0.3 to 0.5 m | | B |
| | | From 0.5 to 1 m | | C |
| | | Above 1 m | | D |

| | | | | |
|---|---|---|---|---|
| | | Others | Specific ……. : | Z |
| 11 | In flooding season, how long does it often last? | Less than 1 day | | A |
| | | 1 day | | B |
| | | 2 - 3 days | | C |
| | | More than 3 days | | D |
| | | Others | Specific ……. : | Z |
| 12 | Have you ever had to be off from work due to flooding? | No | | |
| | | Yes | | |
| 13 | If you can't go to work, how many days off did you have to take? | ….. | Day | |
| 14 | Have you ever heard of climate change? | No | | 0 |
| | | Yes | | 1 |
| 15 | In your opinion, how does climate change affect the precipitation? (Multiple choices possible) | Does not cause any adverse effects | | A |
| | | Result in heavier rain | | B |
| | | Result in more prolonged rain | | C |
| | | Result in higher frequency of precipitation in a short period | | D |
| | | Others | Specific ……. : | Z |
| 16 | | Flooding | | A |
| | | Drought | | B |

| | | | |
|---|---|---|---|
| | In your opinion, how does climate change affect agricultural production? | Soil salinity | C |
| | | Others Specific …….: | D |
| 17 | Do you think that collection of agricultural wastes for bio-organic fertilizer is necessary? | No | 0 |
| | | Yes | 1 |
| 18 | Is this necessary to have the waste treatment facilities in the region for agricultural waste treatment? | No | 0 |
| | | Yes | 1 |
| 19 | Why do you prefer to produce bio-organic fertilizers? (Multiple choices possible) | For agricultural production | A |
| | | For cost effectiveness | B |
| | | For environmental pollution (air, water, soil …) | C |
| | | For better soil quality | D |
| | | Others Specific …….: | Z |
| 20 | According to your opinion, where should the waste treatment facilities located? | …...... | Z |

Appendix D: Survey for staff (Vietnamese)

**Dự án nghiên cứu:**

**Xây dựng Hệ thống tích hợp hỗ trợ lập kế hoạch giảm nhẹ thiện tai lũ lụt hướng tới quản lý chất thải nông nghiệp bền vững tại Đồng bằng Sông Cửu Long (IDSS-MEKONG)**

**Bảng hỏi phỏng vấn cán bộ nhà nước và doanh nghiệp (Chỉ áp dụng cho tỉnh An Giang Việt Nam)**

**SỞ và PHÒNG NÔNG NGHIỆP VÀ PHÁT TRIỂN NÔNG THÔN**

| | |
|---|---|
| Câu 1 | Hiện trạng sản xuất nông nghiệp trên địa bàn tỉnh An Giang:<br>- Diện tích trồng trọt<br>- Cây trồng chính<br>- Khối lượng rác thải từ sản xuất nông nghiệp (tấn?)/năm |
| Câu 2 | Hiện trạng xử lý rác thải nông nghiệp trên địa bàn tỉnh An Giang: |
| | - Lượng rác thải nông nghiệp trên địa bàn tỉnh có được xử lý thành phân hữu cơ vi sinh hoặc kết hoặc hữu cơ vi sinh và hữu cơ khoáng không? |
| | - Chính quyền địa phương có biện pháp/ chính sách nào khuyến khích người dân xử lý rác thải nông nghiệp thành phân hữu cơ không? |
| | - Trên địa bàn tỉnh An Giang hiện nay có nhà máy hoặc cơ sở sản xuất phân hữu cơ từ thu gom/mua rác thải hữu cơ từ người dân không?<br>Nếu có, xin anh /chị cho biết tên nhà máy/đơn vị sản xuất? Tổng sản lượng phân hữu cơ sản xuất hàng năm của tỉnh An Giang ước tính bao nhiêu? Chi phí và giá bán mỗi tấn phân hữu cơ là bao nhiêu? |

| | |
|---|---|
| | - Theo anh chị nhà máy xử lý rác thải hữu cơ nên đặt ở đâu để thu gom được toàn bộ rác thải nông nghiệp trên địa bàn tỉnh và cung cấp cho nông dân? Anh chị có khuyến nghị về vị trí cụ thể không? |
| Câu 3 | Xử lý rác thải nông nghiệp |
| | - Theo anh/chị, thời hạn có thể để rác ở bãi tập kết được bao lâu trước khi phải đưa vào sản xuất để không bị ảnh hưởng đến môi trường xung quanh cũng như chất lượng phân bón hữu cơ sau này? |
| | - Thời hạn để lưu kho phân bao lâu là tốt nhất? Sau bao lâu cần phải sử dụng để không ảnh hưởng đến chất lượng phân? |
| | - Người nông dân, doanh nghiệp đang gặp phải những thách thức nào trong việc xử lý rác thải nông nghiệp và hỗ trợ của các Sở, ban, ngành trong tỉnh để giải quyết những thách thức này? |
| Câu 4 | Các loại hình thiên tai và tác động của biến đổi khí hậu nào ảnh hưởng đến ngành sản xuất nông lâm nghiệp tỉnh An Giang ra sao? |
| Câu 5 | Theo anh chị, cơ sở hạ tầng hiện nay của tỉnh có đáp ứng nhu cầu về vận chuyển xử lý rác thải nông nghiệp không? |

**DOANH NGHIỆP/HỘ KINH DOANH LĨNH VỰC XỬ LÝ RÁC THẢI NÔNG NGHIỆP TRÊN ĐỊA BÀN TỈNH AN GIANG**

| | |
|---|---|
| Câu 1 | Doanh nghiệp anh chị hoạt động trong lĩnh vực xử lý rác thải nông nghiệp bao lâu? |
| Câu 2 | Khối lượng rác thải nông nghiệp được doanh nghiệp anh/chị xử lý thành phân bón hữu cơ hàng năm là bao nhiêu? |
| Câu 3 | Doanh nghiệp anh chị hoạt động trong lĩnh vực xử lý rác thải nông nghiệp thành phân bón hữu cơ bao lâu? |

| | |
|---|---|
| Câu 4 | Cơ sở vật chất xử lý rác thải nông nghiệp thành phân bốn hữu cơ của anh/chị bao gồm những gì?<br>- Vị trí nhà máy<br>- Diện tích đất<br>- Công suất<br>- Chi phí xây dựng và trang thiết bị<br>- Chi phí vận hành nhà máy (triệu/năm)<br>- Chi phí vận chuyển phân<br>- Doanh thu (triệu/năm) |
| Câu 5 | Xử lý rác thải nông nghiệp |
| | - Theo anh/chị, thời hạn có thể để rác ở bãi tập kết được bao lâu trước khi phải đưa vào sản xuất để không bị ảnh hưởng đến môi trường xung quanh cũng như chất lượng phân bón hữu cơ sau này? |
| | - Thời hạn để lưu kho phân bao lâu là tốt nhất? Sau bao lâu cần phải sử dụng để không ảnh hưởng đến chất lượng phân? |
| | - Người nông dân, doanh nghiệp đang gặp phải những thách thức nào trong việc xử lý rác thải nông nghiệp và Chính quyền địa phương có hỗ trợ gì cho anh chị kinh doanh trong lĩnh vực xử lý rác thải nông nghiệp thành phân bón hữu cơ? |
| Câu 6 | Doanh  nghiệp của anh/chị có bị ảnh hưởng của biến đổi khí hậu không?<br>- Ảnh hưởng của lũ lụt như thế nào?<br>- Thiệt hại ra sao?<br>- Phương án phòng tránh giảm thiểu tác động của lũ lụt đối với các hoạt động của công ty anh/chị? |

## Appendix E: Demand of fields

| | U-demand (tonnes) | C-demand (tonnes) | 4mushroom (tonnes) | 4energy (tonnes) |
|---|---|---|---|---|
| C1 | 5,446.30 | 3,630.86 | 1,089.26 | 544.63 |
| C2 | 4,648.68 | 3,099.12 | 929.74 | 464.87 |
| C3 | 5,739.84 | 3,826.56 | 1,147.97 | 573.98 |
| C4 | 4,915.66 | 3,277.10 | 983.13 | 491.57 |
| C5 | 5,547.17 | 3,698.11 | 1,109.43 | 554.72 |
| C6 | 4,378.75 | 2,919.17 | 875.75 | 437.88 |
| C7 | 4,585.14 | 3,056.76 | 917.03 | 458.51 |
| C8 | 2,767.01 | 1,844.67 | 553.4 | 276.7 |
| C9 | 4,096.30 | 2,730.86 | 819.26 | 409.63 |
| C10 | 3,397.93 | 2,265.29 | 679.59 | 339.79 |
| C11 | 2,520.73 | 1,680.49 | 504.15 | 252.07 |
| C12 | 2,199.86 | 1,466.57 | 439.97 | 219.99 |
| C13 | 5 | 3.33 | 1 | 0.5 |
| C14 | 1,022.66 | 681.78 | 204.53 | 102.27 |
| C15 | 22,301.28 | 14,867.52 | 4,460.26 | 2,230.13 |
| C16 | 16,986.35 | 11,324.23 | 3,397.27 | 1,698.63 |
| C17 | 14,434.60 | 9,623.06 | 2,886.92 | 1,443.46 |
| C18 | 9,427.68 | 6,285.12 | 1,885.54 | 942.77 |
| C19 | 8,608.79 | 5,739.19 | 1,721.76 | 860.88 |
| C20 | 10,440.36 | 6,960.24 | 2,088.07 | 1,044.04 |
| C21 | 10,079.35 | 6,719.57 | 2,015.87 | 1,007.94 |
| C22 | 10,373.83 | 6,915.89 | 2,074.77 | 1,037.38 |
| C23 | 6,787.08 | 4,524.72 | 1,357.42 | 678.71 |
| C24 | 6,501.49 | 4,334.33 | 1,300.30 | 650.15 |
| C25 | 2,684.03 | 1,789.36 | 536.81 | 268.4 |
| C26 | 1,699.91 | 1,133.28 | 339.98 | 169.99 |
| C27 | 1,059.04 | 706.02 | 211.81 | 105.9 |

| | | | | |
|---|---|---|---|---|
| C28 | 8,576.96 | 5,717.98 | 1,715.39 | 857.7 |
| C29 | 7,060.43 | 4,706.95 | 1,412.09 | 706.04 |
| C30 | 9,233.32 | 6,155.54 | 1,846.66 | 923.33 |
| C31 | 7,180.49 | 4,786.99 | 1,436.10 | 718.05 |
| C32 | 9,380.74 | 6,253.82 | 1,876.15 | 938.07 |
| C33 | 5,359.32 | 3,572.88 | 1,071.86 | 535.93 |
| C34 | 7,262.28 | 4,841.52 | 1,452.46 | 726.23 |
| C35 | 5,902.42 | 3,934.94 | 1,180.48 | 590.24 |
| C36 | 3,896.64 | 2,597.76 | 779.33 | 389.66 |
| C37 | 2,640.64 | 1,760.43 | 528.13 | 264.06 |
| C38 | 4,892.36 | 3,261.58 | 978.47 | 489.24 |
| C39 | 4,224.85 | 2,816.57 | 844.97 | 422.49 |
| C40 | 676.88 | 451.26 | 135.38 | 67.69 |
| C41 | 440 | 293.33 | 88 | 44 |
| C42 | 27,409.39 | 18,272.93 | 5,481.88 | 2,740.94 |
| C43 | 24,159.92 | 16,106.62 | 4,831.98 | 2,415.99 |
| C44 | 17,234.14 | 11,489.42 | 3,446.83 | 1,723.41 |
| C45 | 13,126.00 | 8,750.66 | 2,625.20 | 1,312.60 |
| C46 | 11,365.09 | 7,576.73 | 2,273.02 | 1,136.51 |
| C47 | 8,374.14 | 5,582.76 | 1,674.83 | 837.41 |
| C48 | 11,838.31 | 7,892.21 | 2,367.66 | 1,183.83 |
| C49 | 7,698.10 | 5,132.06 | 1,539.62 | 769.81 |
| C50 | 7,479.97 | 4,986.65 | 1,495.99 | 748 |
| C51 | 7,563.20 | 5,042.14 | 1,512.64 | 756.32 |
| C52 | 7,173.32 | 4,782.22 | 1,434.66 | 717.33 |
| C53 | 5,606.53 | 3,737.69 | 1,121.31 | 560.65 |
| C54 | 7,877.66 | 5,251.78 | 1,575.53 | 787.77 |
| C55 | 1,937.95 | 1,291.97 | 387.59 | 193.79 |
| C56 | 1,998.96 | 1,332.64 | 399.79 | 199.9 |
| C57 | 8,191.91 | 5,461.27 | 1,638.38 | 819.19 |
| C58 | 6,429.42 | 4,286.28 | 1,285.88 | 642.94 |
| C59 | 5,609.05 | 3,739.37 | 1,121.81 | 560.91 |

| | | | | |
|---|---|---|---|---|
| C60 | 3,484.18 | 2,322.79 | 696.84 | 348.42 |
| C61 | 2,814.09 | 1,876.06 | 562.82 | 281.41 |
| C62 | 5,405.08 | 3,603.38 | 1,081.02 | 540.51 |
| C63 | 3,840.01 | 2,560.01 | 768 | 384 |
| C64 | 3,572.38 | 2,381.58 | 714.48 | 357.24 |
| C65 | 3,653.64 | 2,435.76 | 730.73 | 365.36 |
| C66 | 3,048.27 | 2,032.18 | 609.65 | 304.83 |
| C67 | 3,847.18 | 2,564.78 | 769.44 | 384.72 |
| C68 | 3,688.49 | 2,458.99 | 737.7 | 368.85 |
| C69 | 589.58 | 393.05 | 117.92 | 58.96 |
| C70 | 883.01 | 588.67 | 176.6 | 88.3 |
| C71 | 168.14 | 112.09 | 33.63 | 16.81 |
| C72 | 11,799.86 | 7,866.58 | 2,359.97 | 1,179.99 |
| C73 | 11,375.57 | 7,583.71 | 2,275.11 | 1,137.56 |
| C74 | 11,646.61 | 7,764.41 | 2,329.32 | 1,164.66 |
| C75 | 10,335.60 | 6,890.40 | 2,067.12 | 1,033.56 |
| C76 | 11,246.58 | 7,497.72 | 2,249.32 | 1,124.66 |
| C77 | 9,594.83 | 6,396.55 | 1,918.97 | 959.48 |
| C78 | 8,679.42 | 5,786.28 | 1,735.88 | 867.94 |
| C79 | 10,098.00 | 6,732.00 | 2,019.60 | 1,009.80 |
| C80 | 8,987.83 | 5,991.89 | 1,797.57 | 898.78 |
| C81 | 8,649.90 | 5,766.60 | 1,729.98 | 864.99 |
| C82 | 9,014.11 | 6,009.41 | 1,802.82 | 901.41 |
| C83 | 7,989.55 | 5,326.37 | 1,597.91 | 798.96 |
| C84 | 8,334.00 | 5,556.00 | 1,666.80 | 833.4 |
| C85 | 5,273.50 | 3,515.66 | 1,054.70 | 527.35 |
| C86 | 2,361.20 | 1,574.13 | 472.24 | 236.12 |
| C87 | 1,737.36 | 1,158.24 | 347.47 | 173.74 |
| C88 | 1,499.14 | 999.43 | 299.83 | 149.91 |
| C89 | 17,234.14 | 11,489.42 | 3,446.83 | 1,723.41 |
| C90 | 13,126.00 | 8,750.66 | 2,625.20 | 1,312.60 |
| C91 | 11,365.09 | 7,576.73 | 2,273.02 | 1,136.51 |

| | | | | |
|---|---|---|---|---|
| C92 | 8,374.14 | 5,582.76 | 1,674.83 | 837.41 |
| C93 | 11,838.31 | 7,892.21 | 2,367.66 | 1,183.83 |
| C94 | 7,698.10 | 5,132.06 | 1,539.62 | 769.81 |
| C95 | 7,479.97 | 4,986.65 | 1,495.99 | 748 |
| C96 | 7,563.20 | 5,042.14 | 1,512.64 | 756.32 |
| C97 | 7,173.32 | 4,782.22 | 1,434.66 | 717.33 |
| C98 | 5,606.53 | 3,737.69 | 1,121.31 | 560.65 |
| C99 | 7,877.66 | 5,251.78 | 1,575.53 | 787.77 |
| C100 | 1,937.95 | 1,291.97 | 387.59 | 193.79 |
| C101 | 1,998.96 | 1,332.64 | 399.79 | 199.9 |
| C102 | 8,191.91 | 5,461.27 | 1,638.38 | 819.19 |
| C103 | 6,429.42 | 4,286.28 | 1,285.88 | 642.94 |
| C104 | 5,609.05 | 3,739.37 | 1,121.81 | 560.91 |
| C105 | 3,484.18 | 2,322.79 | 696.84 | 348.42 |
| C106 | 2,814.09 | 1,876.06 | 562.82 | 281.41 |
| C107 | 5,405.08 | 3,603.38 | 1,081.02 | 540.51 |
| C108 | 3,840.01 | 2,560.01 | 768 | 384 |
| C109 | 3,572.38 | 2,381.58 | 714.48 | 357.24 |
| C110 | 3,653.64 | 2,435.76 | 730.73 | 365.36 |
| C111 | 3,048.27 | 2,032.18 | 609.65 | 304.83 |
| C112 | 3,847.18 | 2,564.78 | 769.44 | 384.72 |
| C113 | 3,688.49 | 2,458.99 | 737.7 | 368.85 |
| C114 | 589.58 | 393.05 | 117.92 | 58.96 |
| C115 | 883.01 | 588.67 | 176.6 | 88.3 |
| C116 | 168.14 | 112.09 | 33.63 | 16.81 |
| C117 | 4,950.47 | 3,300.31 | 990.09 | 495.05 |
| C118 | 3,432.34 | 2,288.23 | 686.47 | 343.23 |
| C119 | 2,542.01 | 1,694.67 | 508.4 | 254.2 |
| C120 | 776.07 | 517.38 | 155.21 | 77.61 |
| C121 | 2,840.25 | 1,893.50 | 568.05 | 284.03 |
| C122 | 2,391.67 | 1,594.45 | 478.33 | 239.17 |
| C123 | 921.95 | 614.63 | 184.39 | 92.19 |

| | | | | |
|---|---|---|---|---|
| C124 | 8,547.30 | 5,698.20 | 1,709.46 | 854.73 |
| C125 | 7,428.17 | 4,952.11 | 1,485.63 | 742.82 |
| C126 | 7,152.77 | 4,768.51 | 1,430.55 | 715.28 |
| C127 | 5,576.15 | 3,717.43 | 1,115.23 | 557.61 |
| C128 | 6,610.03 | 4,406.69 | 1,322.01 | 661 |
| C129 | 11,799.86 | 7,866.58 | 2,359.97 | 1,179.99 |
| C130 | 11,375.57 | 7,583.71 | 2,275.11 | 1,137.56 |
| C131 | 11,646.61 | 7,764.41 | 2,329.32 | 1,164.66 |
| C132 | 10,335.60 | 6,890.40 | 2,067.12 | 1,033.56 |
| C133 | 11,246.58 | 7,497.72 | 2,249.32 | 1,124.66 |
| C134 | 9,594.83 | 6,396.55 | 1,918.97 | 959.48 |
| C135 | 8,679.42 | 5,786.28 | 1,735.88 | 867.94 |
| C136 | 10,098.00 | 6,732.00 | 2,019.60 | 1,009.80 |
| C137 | 8,987.83 | 5,991.89 | 1,797.57 | 898.78 |
| C138 | 8,649.90 | 5,766.60 | 1,729.98 | 864.99 |
| C139 | 9,014.11 | 6,009.41 | 1,802.82 | 901.41 |
| C140 | 7,989.55 | 5,326.37 | 1,597.91 | 798.96 |
| C141 | 8,334.00 | 5,556.00 | 1,666.80 | 833.4 |
| C142 | 5,273.50 | 3,515.66 | 1,054.70 | 527.35 |
| C143 | 2,361.20 | 1,574.13 | 472.24 | 236.12 |
| C144 | 1,737.36 | 1,158.24 | 347.47 | 173.74 |
| C145 | 1,499.14 | 999.43 | 299.83 | 149.91 |

## Appendix F: Distance matrices (km)

| | FM1 | FM2 | FM3 | FM4 | FM5 | FM6 | FM7 | FM8 | FM9 | FM10 | FM11 | FM12 | FM13 | FM14 | FM15 | FM16 | FM17 | FM18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C1 | 55.1 | 50.9 | 60.8 | 50.1 | 52 | 59.5 | 57.5 | 51.4 | 49.7 | 57.1 | 61.7 | 40.9 | 20.5 | 14.9 | 7.9 | 30.8 | 33 | 19.5 |
| C2 | 48.2 | 44.6 | 52.2 | 44.6 | 48.8 | 55.2 | 52.4 | 50.1 | 49 | 54.6 | 58.9 | 41.6 | 14.2 | 10.9 | 11.9 | 34.2 | 36.5 | 24.7 |
| C3 | 51.1 | 46.9 | 57 | 46.1 | 48.3 | 55.6 | 53.6 | 48.1 | 46.5 | 53.5 | 58.1 | 38.1 | 20.4 | 10.9 | 5.4 | 28.8 | 31.1 | 18.2 |
| C4 | 58.1 | 53.9 | 63.5 | 53.1 | 55.1 | 62.6 | 60.6 | 54.3 | 52.6 | 60.1 | 64.8 | 43.6 | 20.4 | 18 | 10.8 | 33.1 | 35.2 | 21.5 |
| C5 | 46.3 | 42.4 | 51.4 | 42 | 45.5 | 52.2 | 49.7 | 46.4 | 45.2 | 51.1 | 55.5 | 37.7 | 18.2 | 7.3 | 8.7 | 30.2 | 32.5 | 21 |
| C6 | 47.4 | 43.3 | 53.3 | 42.6 | 45.2 | 52.3 | 50.1 | 45.5 | 44.1 | 50.6 | 55.1 | 36.2 | 20.4 | 7.4 | 5.8 | 27.9 | 30.3 | 18.3 |
| C7 | 47.5 | 43.5 | 53 | 43 | 46 | 53 | 50.6 | 46.5 | 45.3 | 51.5 | 56 | 37.4 | 19 | 7.9 | 7.2 | 29.4 | 31.7 | 19.8 |
| C8 | 52.3 | 48.3 | 57.7 | 47.6 | 50.2 | 57.4 | 55.2 | 50.2 | 48.7 | 55.5 | 60.1 | 40.3 | 18.5 | 12.4 | 7.6 | 31 | 33.3 | 20.3 |
| C9 | 53.5 | 49.5 | 58.9 | 48.8 | 51.3 | 58.5 | 56.4 | 51.1 | 49.6 | 56.6 | 61.1 | 41.1 | 18.5 | 13.6 | 8.2 | 31.6 | 33.8 | 20.6 |
| C10 | 51.8 | 47.8 | 57 | 47.2 | 50 | 57.1 | 54.8 | 50 | 48.6 | 55.3 | 59.8 | 40.3 | 18 | 12 | 7.8 | 31.2 | 33.5 | 20.6 |
| C11 | 2.5 | 4.9 | 17.7 | 8.7 | 20.1 | 15.9 | 10.2 | 29.8 | 32.3 | 25.1 | 25.3 | 37.4 | 57 | 40.5 | 49.5 | 46.2 | 47.1 | 50.3 |
| C12 | 4.4 | 3 | 17.7 | 7.9 | 20.4 | 18.4 | 13 | 29.7 | 31.8 | 26.2 | 27.3 | 35.6 | 52.1 | 35.9 | 45 | 43.3 | 44.4 | 46.5 |
| C13 | 1.4 | 5.3 | 15.3 | 10.2 | 22.4 | 19 | 13.4 | 31.9 | 34.2 | 27.8 | 28.3 | 38.5 | 54.4 | 39 | 48.2 | 46.5 | 47.5 | 49.8 |
| C14 | 4 | 7.6 | 13 | 12.6 | 25 | 22 | 16.4 | 34.4 | 36.6 | 30.6 | 31.2 | 40.3 | 52.5 | 38.3 | 47.7 | 47.5 | 48.7 | 50.2 |
| C15 | 5.8 | 11.3 | 9.6 | 16.1 | 28.1 | 23.8 | 18.2 | 37.8 | 40.2 | 33.3 | 33.3 | 44.5 | 56 | 42.8 | 52.2 | 52.1 | 53.3 | 54.9 |
| C16 | 6.9 | 9.3 | 12.5 | 14.1 | 26.6 | 24.4 | 18.9 | 35.7 | 37.7 | 32.5 | 33.5 | 40.7 | 49.9 | 36.5 | 46.1 | 47.2 | 48.5 | 49.2 |
| C17 | 3.8 | 8.9 | 11.7 | 13.8 | 25.9 | 22.2 | 16.5 | 35.5 | 37.8 | 31.3 | 31.6 | 41.9 | 54.5 | 40.6 | 50 | 49.5 | 50.7 | 52.3 |
| C18 | 18.3 | 23.8 | 5.1 | 28.7 | 40.5 | 35.1 | 29.7 | 50.2 | 52.6 | 45.2 | 44.6 | 57 | 60.9 | 52 | 61.7 | 64.1 | 65.3 | 65.8 |
| C19 | 23.7 | 29.4 | 10.4 | 34.1 | 45.7 | 39.9 | 34.7 | 55.5 | 58 | 50.2 | 49.4 | 62.6 | 64.9 | 57.2 | 66.9 | 69.7 | 71 | 71.4 |
| C20 | 18 | 23.8 | 10.2 | 28.1 | 39 | 32.4 | 27.5 | 48.8 | 51.5 | 43 | 41.8 | 56.9 | 66.1 | 55.4 | 64.9 | 65.2 | 66.2 | 68 |
| C21 | 15.4 | 20.5 | 0.2 | 25.5 | 37.7 | 33.3 | 27.7 | 47.3 | 49.5 | 42.9 | 42.8 | 53.2 | 56.2 | 47.1 | 56.8 | 59.8 | 61.1 | 61.2 |
| C22 | 8.9 | 14.1 | 6.5 | 19 | 31.2 | 26.9 | 21.3 | 40.8 | 43.1 | 36.3 | 36.4 | 47.1 | 55.6 | 43.7 | 53.3 | 54.3 | 55.6 | 56.6 |
| C23 | 20.3 | 26.1 | 10.3 | 30.6 | 41.7 | 35.2 | 30.3 | 51.5 | 54.2 | 45.8 | 44.6 | 59.3 | 66.4 | 56.6 | 66.3 | 67.3 | 68.4 | 69.8 |
| C24 | 24.3 | 30.1 | 14.6 | 34.4 | 45 | 38 | 33.3 | 54.8 | 57.6 | 48.8 | 47.2 | 63.2 | 70.6 | 61.1 | 70.8 | 71.4 | 72.5 | 74.1 |
| C25 | 12.1 | 17.6 | 3.8 | 22.5 | 34.4 | 29.7 | 24.2 | 44.1 | 46.5 | 39.4 | 39.2 | 50.6 | 57.4 | 46.7 | 56.3 | 57.8 | 59.1 | 59.9 |
| C26 | 23.8 | 29.6 | 13.1 | 34.1 | 45 | 38.3 | 33.5 | 54.8 | 57.5 | 48.9 | 47.6 | 62.8 | 68.9 | 59.9 | 69.5 | 70.8 | 71.9 | 73.2 |
| C27 | 12.5 | 18.3 | 5.7 | 22.9 | 34.6 | 29.1 | 23.8 | 44.3 | 46.8 | 39.2 | 38.7 | 51.5 | 60 | 48.8 | 58.4 | 59.2 | 60.3 | 61.6 |
| C28 | 28.2 | 34.1 | 16.4 | 38.6 | 49.6 | 42.9 | 38 | 59.4 | 62.1 | 53.5 | 52.2 | 67.3 | 71.1 | 63.3 | 73 | 75.1 | 76.2 | 77.2 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C29 | 11.7 | 17.5 | 7.2 | 22 | 33.4 | 27.8 | 22.5 | 43.3 | 45.8 | 38 | 37.3 | 50.7 | 60.7 | 49 | 58.5 | 58.6 | 59.7 | 61.4 |
| C30 | 23.7 | 29.1 | 8.9 | 34 | 46 | 40.9 | 35.5 | 55.7 | 58.1 | 50.9 | 50.4 | 62 | 61.4 | 54.7 | 64.4 | 68.5 | 69.8 | 69.5 |
| C31 | 22.3 | 27.4 | 7 | 32.4 | 44.6 | 40.1 | 34.6 | 54.2 | 56.4 | 49.8 | 49.6 | 59.8 | 58 | 51.5 | 61.2 | 65.9 | 67.3 | 66.5 |
| C32 | 11.1 | 15.5 | 5.7 | 20.4 | 32.9 | 29.5 | 23.8 | 42.2 | 44.4 | 38.4 | 38.9 | 47.6 | 52.3 | 41.6 | 51.3 | 53.9 | 55.3 | 55.4 |
| C33 | 16 | 19.4 | 7.9 | 24.2 | 36.7 | 34.3 | 28.6 | 45.6 | 47.5 | 42.6 | 43.5 | 49.7 | 48.2 | 39.9 | 49.6 | 54.7 | 56.3 | 54.9 |
| C34 | 12.8 | 16.3 | 7.6 | 21.2 | 33.6 | 31 | 25.4 | 42.7 | 44.7 | 39.5 | 40.3 | 47.2 | 49.3 | 39.4 | 49.1 | 52.9 | 54.3 | 53.7 |
| C35 | 17 | 21.2 | 5.2 | 26.1 | 38.6 | 35.4 | 29.8 | 47.8 | 49.8 | 44.3 | 44.8 | 52.5 | 51.2 | 43.4 | 53.1 | 57.9 | 59.4 | 58.4 |
| C36 | 17.7 | 22.4 | 3.5 | 27.3 | 39.7 | 36 | 30.3 | 49.1 | 51.2 | 45.2 | 45.4 | 54.3 | 53.7 | 46 | 55.7 | 60.1 | 61.6 | 60.8 |
| C37 | 27.1 | 32.5 | 12.1 | 37.4 | 49.4 | 44.3 | 38.9 | 59.1 | 61.4 | 54.3 | 53.8 | 65.2 | 62.5 | 57 | 66.7 | 71.5 | 72.9 | 72.2 |
| C38 | 19.3 | 24.2 | 4.2 | 29.2 | 41.5 | 37.4 | 31.8 | 51 | 53.2 | 46.9 | 46.9 | 56.4 | 55.4 | 48.1 | 57.8 | 62.3 | 63.7 | 63 |
| C39 | 19.5 | 22.9 | 9.1 | 27.7 | 40.2 | 37.8 | 32.1 | 49.1 | 50.9 | 46.1 | 47 | 52.8 | 47.8 | 41.4 | 51 | 57.4 | 59 | 57 |
| C40 | 21.6 | 25.2 | 10.1 | 30 | 42.4 | 39.9 | 34.3 | 51.3 | 53.1 | 48.4 | 49.2 | 54.9 | 48.1 | 42.7 | 52.4 | 59.3 | 61 | 58.7 |
| C41 | 23.3 | 24.1 | 19.6 | 27.8 | 39.2 | 39.6 | 34.4 | 46.8 | 47.9 | 45.8 | 47.8 | 47.5 | 36.5 | 30.9 | 40.4 | 49.8 | 51.6 | 47.7 |
| C42 | 16.4 | 17.1 | 16 | 21 | 32.8 | 32.6 | 27.4 | 40.8 | 42.2 | 39.2 | 41 | 43 | 41.2 | 31.2 | 40.9 | 46.8 | 48.5 | 46.4 |
| C43 | 23.2 | 21.5 | 25.7 | 23.7 | 33.3 | 35.8 | 31.3 | 39.5 | 40.2 | 39.9 | 42.8 | 38.6 | 32.6 | 21.7 | 31.4 | 40 | 41.9 | 37.9 |
| C44 | 19 | 17.4 | 22.4 | 20 | 30.4 | 32.1 | 27.4 | 37.3 | 38.3 | 37 | 39.5 | 37.7 | 36.8 | 24.6 | 34.3 | 40.6 | 42.3 | 39.7 |
| C45 | 19.9 | 20.3 | 18.4 | 24 | 35.4 | 35.8 | 30.6 | 43 | 44.3 | 41.9 | 43.9 | 44.2 | 38.1 | 29.8 | 39.5 | 47.1 | 48.9 | 45.8 |
| C46 | 26.4 | 26.2 | 24.1 | 29.4 | 40.1 | 41.4 | 36.5 | 46.8 | 47.7 | 46.7 | 49.1 | 46.3 | 32 | 27.1 | 36.5 | 47.4 | 49.4 | 44.4 |
| C47 | 12.5 | 15 | 10.2 | 19.8 | 32.2 | 30.3 | 24.7 | 41 | 42.8 | 38.2 | 39.3 | 45 | 47.2 | 36.7 | 46.4 | 50.3 | 51.8 | 51 |
| C48 | 24.1 | 23 | 24.8 | 25.7 | 35.8 | 37.8 | 33.1 | 42.2 | 43 | 42.4 | 45.1 | 41.5 | 32.2 | 23.7 | 33.2 | 42.8 | 44.7 | 40.4 |
| C49 | 27.8 | 26.8 | 27.3 | 29.5 | 39.3 | 41.6 | 36.9 | 45.4 | 46.1 | 45.9 | 48.7 | 43.9 | 29 | 23.3 | 32.6 | 44.2 | 46.2 | 40.8 |
| C50 | 18.2 | 20.4 | 12.5 | 24.9 | 37.1 | 35.8 | 30.3 | 45.5 | 47.1 | 43.3 | 44.6 | 48.3 | 43.6 | 36.1 | 45.8 | 52.4 | 54 | 51.8 |
| C51 | 27.1 | 27.8 | 22.5 | 31.4 | 42.6 | 43.3 | 38.1 | 49.9 | 50.9 | 49.2 | 51.4 | 50 | 34 | 31 | 40.3 | 51.4 | 53.3 | 48.4 |
| C52 | 28.3 | 26.5 | 29.7 | 28.5 | 37.5 | 40.5 | 36.2 | 43 | 43.4 | 44.1 | 47.2 | 40.7 | 27.6 | 19.5 | 28.9 | 40.5 | 42.5 | 36.9 |
| C53 | 24 | 21.5 | 27.9 | 23.2 | 32 | 35.2 | 31 | 37.6 | 38.2 | 38.6 | 41.7 | 36.1 | 31.9 | 19.2 | 28.9 | 37.2 | 39.1 | 35.1 |
| C54 | 21.3 | 23.2 | 14.9 | 27.5 | 39.6 | 38.7 | 33.2 | 47.8 | 49.2 | 45.9 | 47.4 | 49.9 | 41.4 | 35.6 | 45.2 | 53.2 | 54.9 | 51.9 |
| C55 | 21.1 | 24 | 11.9 | 28.6 | 41 | 39.2 | 33.6 | 49.6 | 51.3 | 47.1 | 48.2 | 52.6 | 45.1 | 39.5 | 49.1 | 56.5 | 58.2 | 55.6 |
| C56 | 30 | 27.8 | 32.2 | 29.5 | 37.8 | 41.4 | 37.3 | 42.8 | 43 | 44.4 | 47.6 | 39.7 | 25.7 | 17.1 | 26.4 | 38.8 | 40.9 | 34.7 |
| C57 | 23.7 | 26 | 15.4 | 30.4 | 42.6 | 41.4 | 35.9 | 50.8 | 52.3 | 48.9 | 50.3 | 53 | 42 | 37.8 | 47.3 | 56.1 | 57.9 | 54.5 |
| C58 | 30.8 | 28.2 | 33.8 | 29.5 | 37.2 | 41.3 | 37.4 | 41.7 | 41.8 | 43.7 | 47.1 | 38.1 | 25.2 | 14.9 | 24.2 | 36.7 | 38.8 | 32.5 |
| C59 | 31.2 | 29.6 | 31.9 | 31.6 | 40.4 | 43.6 | 39.3 | 45.7 | 46 | 47.1 | 50.2 | 42.9 | 24.8 | 19.5 | 28.5 | 41.8 | 44 | 37.4 |
| C60 | 11.1 | 5.8 | 23.9 | 6 | 16.7 | 18.1 | 13.9 | 24.9 | 26.6 | 23.2 | 25.4 | 29.2 | 48.6 | 30.2 | 39 | 36.4 | 37.5 | 39.8 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C61 | 20.6 | 14.9 | 33.4 | 11.9 | 14.4 | 20.5 | 18.7 | 19.2 | 19.9 | 20.8 | 24.5 | 20.2 | 46.3 | 24.6 | 32.1 | 26.8 | 27.9 | 30.9 |
| C62 | 24.1 | 18.9 | 35 | 17.1 | 20.3 | 26.5 | 24.4 | 23.8 | 23.9 | 26.4 | 30.4 | 21.5 | 40.4 | 18.6 | 26.4 | 24.9 | 26.4 | 26.8 |
| C63 | 8.6 | 7.7 | 17 | 11.7 | 23.8 | 23.2 | 18 | 32.5 | 34.2 | 30.1 | 31.7 | 36.6 | 47.2 | 32.4 | 41.8 | 42.7 | 44.1 | 44.6 |
| C64 | 13.1 | 10.9 | 20.5 | 13.6 | 24.6 | 25.6 | 20.9 | 32.3 | 33.6 | 31.1 | 33.3 | 34.6 | 42.8 | 27.7 | 37.2 | 39.5 | 41 | 40.6 |
| C65 | 18.2 | 13.2 | 28.9 | 12.5 | 19.3 | 23.5 | 20.3 | 25.2 | 26 | 25.9 | 29.1 | 25.9 | 42.4 | 22.9 | 31.6 | 30.8 | 32.2 | 32.9 |
| C66 | 28.2 | 24.8 | 33.9 | 25.3 | 31.9 | 36.7 | 33.2 | 36.1 | 36.1 | 38.4 | 42 | 32.5 | 29.2 | 13.1 | 22.8 | 31.9 | 33.9 | 29 |
| C67 | 27.1 | 22.7 | 35.4 | 22.1 | 26.9 | 32.6 | 29.8 | 30.3 | 30.2 | 33.1 | 37 | 26.5 | 33.8 | 13.3 | 22.3 | 26.9 | 28.8 | 25.8 |
| C68 | 17.7 | 14.4 | 25.3 | 15.7 | 24.8 | 27.6 | 23.5 | 31.2 | 32.2 | 31.4 | 34.3 | 31.7 | 39.1 | 22.8 | 32.2 | 35.3 | 37 | 35.8 |
| C69 | 22.6 | 18.8 | 30 | 19.3 | 26.5 | 30.7 | 27.2 | 31.5 | 32 | 33 | 36.4 | 29.9 | 35.3 | 17.7 | 27.2 | 31.8 | 33.6 | 31.2 |
| C70 | 12.7 | 13.3 | 15 | 17.4 | 29.4 | 28.9 | 23.6 | 37.8 | 39.4 | 35.8 | 37.4 | 40.8 | 44 | 32.1 | 41.8 | 45.7 | 47.2 | 46.2 |
| C71 | 31.5 | 28.4 | 35.8 | 29.3 | 36 | 40.7 | 37.2 | 39.9 | 39.9 | 42.4 | 46.1 | 35.6 | 25.2 | 12.1 | 21.6 | 33.8 | 36 | 29.5 |
| C72 | 20.9 | 17.7 | 27.4 | 18.8 | 27.2 | 30.6 | 26.7 | 33 | 33.7 | 33.9 | 36.9 | 32.2 | 35.8 | 20 | 29.5 | 34.6 | 36.4 | 34 |
| C73 | 23.9 | 18.3 | 38.8 | 13.5 | 5.4 | 14.5 | 15.8 | 9.2 | 10.8 | 10.7 | 15 | 16 | 56.2 | 33.2 | 39.2 | 27.1 | 27.3 | 34.7 |
| C74 | 17.2 | 13.2 | 32.5 | 8.9 | 6.3 | 4.4 | 5.7 | 16 | 18.9 | 10.3 | 11.1 | 26.3 | 61.7 | 40.7 | 47.9 | 37.7 | 38 | 44.9 |
| C75 | 21 | 18 | 35.9 | 14.2 | 8.9 | 2.6 | 8.3 | 16.5 | 19.6 | 8.7 | 6.9 | 28.6 | 67.4 | 46 | 52.9 | 40.9 | 40.9 | 49 |
| C76 | 19.2 | 13.4 | 33.7 | 8.9 | 8.2 | 14.6 | 13.7 | 14.8 | 16.3 | 14.8 | 18.3 | 19.8 | 52.5 | 30.7 | 37.7 | 29.2 | 29.9 | 35.2 |
| C77 | 23.9 | 18.1 | 37.8 | 14 | 11 | 19.1 | 18.9 | 13.7 | 14.3 | 16.6 | 20.9 | 15.3 | 50.3 | 27.3 | 33.6 | 23.9 | 24.7 | 30.1 |
| C78 | 11.3 | 6.7 | 26.6 | 2.8 | 11.1 | 9.4 | 5.3 | 20.8 | 23.3 | 16.5 | 17.6 | 28.9 | 57.2 | 37.6 | 45.7 | 38.8 | 39.4 | 44.4 |
| C79 | 13.9 | 8.6 | 29 | 3.6 | 8.9 | 10.3 | 7.8 | 18.2 | 20.5 | 15.1 | 17 | 25.7 | 55.6 | 35.2 | 42.9 | 35.4 | 36.1 | 41.2 |
| C80 | 7.7 | 4.7 | 23.1 | 4.4 | 14.7 | 11.1 | 5.7 | 24.5 | 27 | 19.8 | 20.2 | 32.6 | 57.6 | 39.2 | 47.7 | 42.2 | 42.9 | 47.2 |
| C81 | 16.6 | 14.8 | 31.1 | 12.2 | 12.3 | 3.1 | 4.5 | 21.1 | 24.2 | 13.9 | 12.1 | 32.5 | 66.6 | 46.4 | 54 | 44.2 | 44.4 | 51.3 |
| C82 | 12.9 | 12.2 | 26.8 | 11 | 15.3 | 7.2 | 3.8 | 24.7 | 27.7 | 17.9 | 16.5 | 35.3 | 65.2 | 46.2 | 54.3 | 46.3 | 46.7 | 52.7 |
| C83 | 7.8 | 8.1 | 22 | 9 | 17.5 | 11.3 | 6 | 27.3 | 30.1 | 21.5 | 20.9 | 36.5 | 61.5 | 43.7 | 52.3 | 46.5 | 47.2 | 51.8 |
| C84 | 16 | 10.2 | 30.5 | 5.8 | 9.5 | 13.5 | 11.5 | 17.4 | 19.2 | 16.1 | 18.9 | 23 | 52.5 | 31.6 | 39.2 | 32.1 | 32.9 | 37.5 |
| C85 | 17.2 | 12 | 32.4 | 7 | 5.6 | 9.7 | 9.2 | 14.8 | 17.1 | 12 | 14.6 | 22.9 | 56.8 | 35.5 | 42.7 | 33.4 | 33.8 | 39.9 |
| C86 | 8.4 | 7 | 23.4 | 6.7 | 15.2 | 9.9 | 4.3 | 25 | 27.8 | 19.6 | 19.4 | 34 | 60.2 | 41.8 | 50.2 | 44 | 44.7 | 49.5 |
| C87 | 38.2 | 33.6 | 53.5 | 28.7 | 16.3 | 21.3 | 26.2 | 9.3 | 10.3 | 10.7 | 12.5 | 19.9 | 72.3 | 48.2 | 52.1 | 33 | 31.9 | 43.9 |
| C88 | 39.2 | 33.4 | 52.9 | 29.1 | 21.6 | 31 | 32.6 | 15.5 | 12.8 | 23.4 | 28.3 | 2.7 | 53.1 | 28.6 | 30.4 | 11 | 10.7 | 21.4 |
| C89 | 35.3 | 31.8 | 50.2 | 27.4 | 16.6 | 17 | 22.6 | 15 | 17.4 | 10 | 7.6 | 27.8 | 76.7 | 53.4 | 58.4 | 41.1 | 40.3 | 51.4 |
| C90 | 30.5 | 24.7 | 44.3 | 20.6 | 14.9 | 24 | 24.8 | 12.8 | 11.8 | 18.7 | 23.5 | 9 | 50.5 | 26.4 | 30.9 | 17.7 | 18.2 | 25.3 |
| C91 | 36.5 | 30.9 | 51.2 | 26.1 | 16.3 | 25.5 | 28.1 | 8.5 | 5.6 | 16.7 | 21.4 | 4.9 | 58.6 | 34.1 | 37.1 | 18.2 | 17.5 | 28.7 |
| C92 | 31.5 | 26.9 | 46.8 | 22.1 | 9.7 | 14.9 | 19.7 | 6.2 | 9 | 4.1 | 7.5 | 19.4 | 68.1 | 44.5 | 49.4 | 32.7 | 32.1 | 42.7 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C93 | 34.2 | 31.6 | 48.6 | 27.7 | 18.7 | 16 | 21.6 | 19.6 | 22.2 | 12.8 | 8.5 | 32.7 | 79.3 | 56.6 | 62.2 | 46 | 45.3 | 56 |
| C94 | 27.2 | 21.9 | 42.3 | 16.9 | 5.9 | 15.2 | 17.7 | 5.1 | 7.2 | 8.2 | 13 | 14.5 | 59.4 | 36 | 41.3 | 26.8 | 26.7 | 35.6 |
| C95 | 30.6 | 25 | 45.4 | 20.2 | 10.2 | 19.6 | 21.9 | 5.3 | 5 | 11.9 | 16.9 | 10.1 | 57.9 | 33.9 | 38.3 | 22.6 | 22.4 | 31.8 |
| C96 | 38.2 | 32.8 | 53.3 | 27.8 | 16.3 | 24.7 | 28.2 | 6.6 | 3.8 | 14.5 | 18.7 | 9.8 | 64.1 | 39.6 | 42.6 | 22.8 | 21.8 | 33.9 |
| C97 | 34 | 29.1 | 49.4 | 24.1 | 11.7 | 18.8 | 23 | 3.4 | 5 | 8.1 | 12 | 15.4 | 66.4 | 42.4 | 46.6 | 28.7 | 27.9 | 39.1 |
| C98 | 24.1 | 20.3 | 39.4 | 15.9 | 6.4 | 6.7 | 11.7 | 12.2 | 15.4 | 4.2 | 4.2 | 24.8 | 66.9 | 44.6 | 50.9 | 37.4 | 37.2 | 46.1 |
| C99 | 28 | 25 | 42.8 | 20.9 | 12.2 | 9.6 | 15.3 | 15.5 | 18.6 | 7.5 | 2.5 | 28.8 | 72.7 | 50.4 | 56.5 | 41.8 | 41.4 | 51.1 |
| C100 | 27.6 | 24.1 | 42.6 | 19.8 | 9.9 | 9.4 | 14.9 | 12.9 | 16 | 4.7 | 0.2 | 26.1 | 70.5 | 48 | 53.9 | 39.1 | 38.7 | 48.4 |
| C101 | 29.6 | 24.1 | 44.6 | 19.2 | 8.9 | 18.2 | 20.7 | 4.5 | 5.1 | 10.5 | 15.5 | 11.5 | 58.6 | 34.7 | 39.5 | 24 | 23.8 | 33.2 |
| C102 | 52.9 | 49.7 | 55.5 | 50.1 | 54.9 | 61 | 58 | 56.4 | 55.4 | 60.8 | 65 | 48 | 8.5 | 17.3 | 17.1 | 40.1 | 42.4 | 30 |
| C103 | 42.2 | 39 | 45.5 | 39.5 | 45 | 50.6 | 47.4 | 47.4 | 46.8 | 51.1 | 55.1 | 40.6 | 15.7 | 10.1 | 16 | 35.2 | 37.5 | 27.5 |
| C104 | 36.4 | 33.4 | 39.7 | 34.3 | 40.7 | 45.7 | 42.2 | 44.1 | 43.7 | 47 | 50.8 | 38.7 | 20.3 | 11 | 19.5 | 35.2 | 37.5 | 29.3 |
| C105 | 36.3 | 33.8 | 38.6 | 35 | 42.1 | 46.7 | 42.9 | 46 | 45.8 | 48.6 | 52.2 | 41.1 | 19.6 | 13.8 | 22 | 38 | 40.3 | 32.1 |
| C106 | 56.8 | 53.6 | 59.4 | 54 | 58.4 | 64.7 | 61.8 | 59.6 | 58.4 | 64.2 | 68.5 | 50.6 | 8.6 | 20.5 | 18.6 | 42 | 44.3 | 31.4 |
| C107 | 41 | 38.3 | 43.2 | 39.3 | 45.8 | 50.8 | 47.2 | 49 | 48.6 | 52.1 | 55.9 | 43 | 15.1 | 13.4 | 19.9 | 38.5 | 40.8 | 31.2 |
| C108 | 53.8 | 50.3 | 57.5 | 50.3 | 54.2 | 60.7 | 58.1 | 55 | 53.7 | 59.8 | 64.2 | 45.8 | 12.3 | 16 | 13.8 | 37.2 | 39.5 | 26.6 |
| C109 | 57.7 | 54.1 | 61.3 | 54 | 57.6 | 64.3 | 61.8 | 58 | 56.6 | 63.1 | 67.5 | 48.4 | 13 | 19.4 | 15.6 | 39 | 41.2 | 27.9 |
| C110 | 45.9 | 43 | 48.5 | 43.6 | 49.2 | 54.8 | 51.5 | 51.5 | 50.8 | 55.3 | 59.3 | 44.3 | 11.6 | 13.4 | 17.2 | 38.2 | 40.5 | 29.5 |
| C111 | 44.7 | 42.5 | 45.2 | 43.9 | 51 | 55.6 | 51.8 | 54.4 | 54 | 57.3 | 61 | 48.5 | 11.1 | 18.5 | 23.7 | 43.6 | 45.9 | 35.7 |
| C112 | 44.5 | 42 | 45.6 | 43.2 | 49.9 | 54.8 | 51.1 | 53.2 | 52.7 | 56.2 | 60 | 47 | 11.4 | 16.7 | 21.8 | 41.8 | 44.2 | 33.9 |
| C113 | 49.3 | 46.5 | 51.4 | 47.2 | 52.7 | 58.3 | 55.1 | 54.9 | 54.1 | 58.8 | 62.8 | 47.3 | 8.3 | 16.3 | 18.5 | 40.5 | 42.9 | 31.3 |
| C114 | 53.1 | 50.4 | 54.6 | 51.2 | 56.8 | 62.4 | 59.1 | 58.9 | 58 | 62.8 | 66.9 | 51.1 | 4.6 | 20.1 | 21.1 | 43.8 | 46.1 | 34 |
| C115 | 49.4 | 46.9 | 50.5 | 47.9 | 54.1 | 59.3 | 55.8 | 56.8 | 56.1 | 60.3 | 64.2 | 49.7 | 6.6 | 18.8 | 21.7 | 43.4 | 45.7 | 34.4 |
| C116 | 39.4 | 37.2 | 40.4 | 38.7 | 46.1 | 50.4 | 46.5 | 50 | 49.8 | 52.5 | 56.1 | 44.9 | 16.4 | 16.5 | 23.6 | 41.2 | 43.5 | 34.6 |
| C117 | 30.3 | 25 | 41 | 22.8 | 23.7 | 31.1 | 29.7 | 24.7 | 24 | 29.2 | 33.6 | 19 | 38.3 | 14.7 | 21.2 | 19.5 | 21.2 | 20.6 |
| C118 | 37 | 31.9 | 46.8 | 29.8 | 29.9 | 37.8 | 36.6 | 29.4 | 28.1 | 34.9 | 39.5 | 20.7 | 34.9 | 10.4 | 14.6 | 16.3 | 18.5 | 14.2 |
| C119 | 33.9 | 29.6 | 41.2 | 28.9 | 32.6 | 39 | 36.5 | 34.5 | 33.9 | 38.5 | 42.7 | 28.2 | 28.6 | 6.4 | 15.6 | 25.1 | 27.3 | 21.2 |
| C120 | 32.4 | 27.6 | 41.4 | 26.2 | 28.6 | 35.5 | 33.5 | 30 | 29.2 | 34.2 | 38.6 | 23.6 | 33.1 | 9.6 | 17.3 | 21.6 | 23.7 | 19.7 |
| C121 | 42.2 | 37.9 | 48.6 | 37.3 | 40.2 | 47.1 | 44.8 | 41 | 39.9 | 45.8 | 50.2 | 32.5 | 23 | 2 | 8.3 | 26 | 28.3 | 18.2 |
| C122 | 29.3 | 23.6 | 41.7 | 20.4 | 18.6 | 26.8 | 26.3 | 18.8 | 18 | 23.6 | 28.2 | 13.9 | 44.4 | 20.5 | 26 | 18.1 | 19.3 | 22.6 |
| C123 | 40.3 | 35.6 | 48.2 | 34.4 | 36.1 | 43.5 | 41.7 | 36.3 | 35 | 41.4 | 45.9 | 27.5 | 28.1 | 3.9 | 9.2 | 21.2 | 23.6 | 14.9 |
| C124 | 44.9 | 40.3 | 52.5 | 39 | 40.3 | 47.9 | 46.2 | 39.8 | 38.3 | 45.4 | 50 | 30.1 | 26.5 | 5.9 | 4.5 | 21.9 | 24.2 | 13.1 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C125 | 33.8 | 28.1 | 45.9 | 24.9 | 22.1 | 30.8 | 30.6 | 20.5 | 19.1 | 26.4 | 31.2 | 12.4 | 43.6 | 19.1 | 23.1 | 13.7 | 15.2 | 18.3 |
| C126 | 38.3 | 34.3 | 44.4 | 33.9 | 37.7 | 44.1 | 41.6 | 39.4 | 38.5 | 43.5 | 47.8 | 32.1 | 23.8 | 2.8 | 12.4 | 27.2 | 29.5 | 20.9 |
| C127 | 34.4 | 30.7 | 40 | 30.8 | 35.9 | 41.6 | 38.6 | 38.7 | 38.2 | 42.1 | 46.1 | 32.9 | 24.7 | 7.3 | 16.9 | 29.8 | 32 | 24.8 |
| C128 | 43.6 | 39.8 | 48.6 | 39.6 | 43.6 | 50 | 47.4 | 45 | 44 | 49.4 | 53.7 | 36.9 | 18.6 | 5.9 | 10.5 | 30.4 | 32.7 | 22.1 |
| C129 | 53.9 | 49.2 | 61.4 | 47.6 | 47.8 | 56 | 54.7 | 46 | 44.1 | 52.4 | 57.2 | 34.7 | 27.7 | 14.5 | 4.8 | 23.7 | 25.8 | 12.1 |
| C130 | 44.9 | 39.5 | 54.9 | 37.1 | 35.4 | 44 | 43.4 | 32.8 | 30.8 | 39.5 | 44.3 | 21.5 | 36.3 | 13.7 | 11.8 | 12 | 14.4 | 6.1 |
| C131 | 40.1 | 34.8 | 50.3 | 32.4 | 31.2 | 39.6 | 38.8 | 29.6 | 27.9 | 35.7 | 40.5 | 19.4 | 36.5 | 12.3 | 14 | 13.1 | 15.4 | 10.8 |
| C132 | 49 | 43.8 | 58.1 | 41.7 | 40.6 | 49.1 | 48.3 | 38.1 | 36.1 | 44.8 | 49.6 | 26.5 | 33.4 | 13.5 | 7.9 | 15.8 | 18 | 5.2 |
| C133 | 37.5 | 31.8 | 49.8 | 28.3 | 24.2 | 33.2 | 33.5 | 20.9 | 19 | 27.7 | 32.6 | 10.5 | 45.1 | 20.6 | 22.9 | 9.9 | 11.2 | 16 |
| C134 | 53.9 | 48.8 | 62.4 | 46.9 | 45.9 | 54.4 | 53.6 | 43.3 | 41.1 | 50 | 54.9 | 31.4 | 32.2 | 16.3 | 7.6 | 19.7 | 21.7 | 7.8 |
| C135 | 56.2 | 51.7 | 63.1 | 50.4 | 51.1 | 59.1 | 57.6 | 49.6 | 47.7 | 55.8 | 60.6 | 38.4 | 25.4 | 16.2 | 6.9 | 27.3 | 29.4 | 15.6 |
| C136 | 43.2 | 37.6 | 54.4 | 34.6 | 31.4 | 40.3 | 40.3 | 27.9 | 25.7 | 34.9 | 39.8 | 16.1 | 41.3 | 17.7 | 17.2 | 7.5 | 9.8 | 8.8 |
| C137 | 48.3 | 42.5 | 60.1 | 39.1 | 34.2 | 43.5 | 44.2 | 29.1 | 26.5 | 36.8 | 41.8 | 16.1 | 45.9 | 23.2 | 20.7 | 3 | 5 | 8.8 |
| C138 | 49.6 | 44 | 60.5 | 41.1 | 37.5 | 46.6 | 46.7 | 33.2 | 30.7 | 40.6 | 45.5 | 20.5 | 41.7 | 20.2 | 16.2 | 8 | 10 | 3.9 |
| C139 | 42.1 | 36.3 | 54.5 | 32.8 | 27.7 | 36.9 | 37.6 | 23.1 | 20.6 | 30.5 | 35.4 | 10.6 | 46.6 | 22.6 | 22.9 | 5.2 | 6.6 | 13.5 |
| C140 | 53.2 | 47.5 | 65 | 44.1 | 38.8 | 48.2 | 49 | 33.1 | 30.3 | 41.1 | 45.9 | 19.8 | 47.6 | 26.3 | 22 | 6.7 | 7.3 | 9.1 |
| C141 | 45.1 | 39.3 | 58.1 | 35.4 | 28.9 | 38.3 | 39.6 | 22.9 | 20.1 | 30.9 | 35.7 | 9.6 | 50.6 | 26.7 | 26.2 | 3.8 | 3.3 | 15.3 |
| C142 | 48.1 | 43.4 | 56 | 41.8 | 42.3 | 50.3 | 48.9 | 41.1 | 39.4 | 47.1 | 51.8 | 30.5 | 27.8 | 9.5 | 2.6 | 20.9 | 23.2 | 10.7 |
| C143 | 50 | 44.2 | 62.4 | 40.5 | 34.4 | 43.8 | 45 | 28.2 | 25.4 | 36.3 | 41.1 | 14.9 | 49.8 | 27.2 | 24.6 | 2.7 | 2.3 | 12.3 |
| C144 | 51.5 | 46.1 | 61.7 | 43.4 | 40.6 | 49.5 | 49.4 | 36.8 | 34.4 | 44 | 48.9 | 24.2 | 39 | 19 | 13.4 | 11.8 | 13.7 | 0.7 |
| C145 | 50 | 45.6 | 56.5 | 44.5 | 46.2 | 53.8 | 51.9 | 45.7 | 44.1 | 51.3 | 55.9 | 35.5 | 22.9 | 9.8 | 2.7 | 26.1 | 28.4 | 15.6 |

| | FE1 | FE2 | FE3 | FE4 | FE5 | FE6 | FE7 |
|---|---|---|---|---|---|---|---|
| C1 | 27.28 | 36.97 | 45.07 | 43.58 | 56.29 | 61.98 | 47.45 |
| C2 | 18.31 | 28.85 | 43.37 | 41.66 | 55.6 | 60.84 | 45.22 |
| C3 | 23.66 | 33.1 | 41.64 | 40.1 | 53.14 | 58.73 | 43.92 |
| C4 | 29.84 | 39.78 | 48.03 | 46.57 | 59.12 | 64.86 | 50.46 |
| C5 | 17.91 | 27.67 | 39.71 | 38.03 | 51.81 | 57.13 | 41.66 |
| C6 | 20.17 | 29.41 | 38.94 | 37.33 | 50.76 | 56.22 | 41.08 |
| C7 | 19.6 | 29.19 | 39.95 | 38.31 | 51.88 | 57.29 | 42.02 |
| C8 | 24.04 | 33.9 | 43.69 | 42.12 | 55.27 | 60.84 | 45.92 |
| C9 | 25.19 | 35.1 | 44.7 | 43.15 | 56.2 | 61.8 | 46.97 |
| C10 | 23.39 | 33.3 | 43.54 | 41.96 | 55.2 | 60.74 | 45.74 |
| C11 | 32.48 | 21.56 | 27.25 | 26.32 | 34.8 | 35.06 | 24.75 |
| C12 | 27.61 | 16.74 | 26.06 | 24.84 | 35.16 | 36.24 | 24 |
| C13 | 29.94 | 18.88 | 28.73 | 27.62 | 37.16 | 37.78 | 26.49 |
| C14 | 28.26 | 17.12 | 30.8 | 29.57 | 39.77 | 40.62 | 28.74 |
| C15 | 32.03 | 20.97 | 34.73 | 33.61 | 42.9 | 43.2 | 32.46 |
| C16 | 25.8 | 14.69 | 31.7 | 30.34 | 41.32 | 42.51 | 29.88 |
| C17 | 30.34 | 19.21 | 32.26 | 31.11 | 40.73 | 41.26 | 30.05 |
| C18 | 38.96 | 28.97 | 47.26 | 46.13 | 55.11 | 54.97 | 44.96 |
| C19 | 43.77 | 34.16 | 52.77 | 51.68 | 60.27 | 59.85 | 50.41 |
| C20 | 43.3 | 32.73 | 46.71 | 45.8 | 53.24 | 52.42 | 44.11 |
| C21 | 34.06 | 24.06 | 43.85 | 42.61 | 52.47 | 52.81 | 41.75 |
| C22 | 32.12 | 21.29 | 37.53 | 36.35 | 45.93 | 46.28 | 35.34 |
| C23 | 44.09 | 33.79 | 49.24 | 48.29 | 56.01 | 55.26 | 46.7 |
| C24 | 48.5 | 38.25 | 52.91 | 52.04 | 59.08 | 57.97 | 50.26 |
| C25 | 34.45 | 23.9 | 41.01 | 39.85 | 49.17 | 49.32 | 38.77 |
| C26 | 47.03 | 36.92 | 52.66 | 51.72 | 59.21 | 58.3 | 50.08 |
| C27 | 36.9 | 26.22 | 41.6 | 40.54 | 49.18 | 49 | 39.21 |
| C28 | 50.02 | 40.29 | 57.19 | 56.23 | 63.8 | 62.85 | 54.64 |
| C29 | 37.39 | 26.58 | 40.69 | 39.68 | 48 | 47.7 | 38.23 |
| C30 | 40.84 | 31.71 | 52.5 | 51.3 | 60.73 | 60.7 | 50.32 |
| C31 | 37.48 | 28.56 | 50.64 | 49.35 | 59.39 | 59.69 | 48.6 |

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| C32 | 29.25 | 18.76 | 38.45 | 37.13 | 47.65 | 48.43 | 36.52 |
| C33 | 26.27 | 16.92 | 41.26 | 39.77 | 51.34 | 52.6 | 39.66 |
| C34 | 26.52 | 16.35 | 38.53 | 37.1 | 48.34 | 49.48 | 36.81 |
| C35 | 29.68 | 20.41 | 43.74 | 42.33 | 53.36 | 54.29 | 41.98 |
| C36 | 32.29 | 22.95 | 45.31 | 43.95 | 54.53 | 55.19 | 43.41 |
| C37 | 42.81 | 34.15 | 55.83 | 54.6 | 64.13 | 64.11 | 53.68 |
| C38 | 34.31 | 25.12 | 47.3 | 45.98 | 56.31 | 56.82 | 45.34 |
| C39 | 27.05 | 18.71 | 44.57 | 43.04 | 54.8 | 56.12 | 43.05 |
| C40 | 28.15 | 20.39 | 46.8 | 45.27 | 57.06 | 58.37 | 45.3 |
| C41 | 15.96 | 10.53 | 41.15 | 39.38 | 52.9 | 55.42 | 40.44 |
| C42 | 18.02 | 8.23 | 35.62 | 33.95 | 46.85 | 49.02 | 34.57 |
| C43 | 8.45 | 3.08 | 33.35 | 31.49 | 45.74 | 49.03 | 33.21 |
| C44 | 12.57 | 1.57 | 31.46 | 29.66 | 43.47 | 46.36 | 30.94 |
| C45 | 15.66 | 7.68 | 37.51 | 35.77 | 49.14 | 51.6 | 36.71 |
| C46 | 11.84 | 9.69 | 40.86 | 39.02 | 53.06 | 56.05 | 40.52 |
| C47 | 24.06 | 13.71 | 36.57 | 35.08 | 46.76 | 48.19 | 35 |
| C48 | 9.19 | 5.18 | 36.16 | 34.31 | 48.47 | 51.62 | 35.93 |
| C49 | 7.93 | 8.81 | 39.2 | 37.33 | 51.68 | 55.02 | 39.16 |
| C50 | 22.01 | 13.47 | 40.62 | 39.01 | 51.44 | 53.22 | 39.36 |
| C51 | 15.66 | 12.97 | 44.08 | 42.28 | 56.06 | 58.77 | 43.55 |
| C52 | 4.35 | 8.12 | 36.57 | 34.67 | 49.22 | 52.86 | 36.78 |
| C53 | 7.39 | 4.09 | 31.32 | 29.44 | 43.88 | 47.41 | 31.4 |
| C54 | 20.88 | 13.78 | 42.61 | 40.94 | 53.75 | 55.75 | 41.53 |
| C55 | 24.89 | 17.35 | 44.8 | 43.21 | 55.46 | 57.07 | 43.48 |
| C56 | 1.81 | 9.77 | 36.25 | 34.34 | 49.01 | 52.89 | 36.69 |
| C57 | 22.81 | 16.65 | 45.73 | 44.06 | 56.83 | 58.75 | 44.62 |
| C58 | 1.01 | 10.72 | 35.09 | 33.18 | 47.9 | 51.96 | 35.7 |
| C59 | 4.28 | 11.19 | 39.24 | 37.34 | 51.96 | 55.73 | 39.58 |
| C60 | 24.3 | 14.74 | 20.33 | 18.89 | 30.83 | 32.92 | 18.8 |
| C61 | 23.96 | 18.13 | 13.06 | 11.25 | 25.42 | 29.04 | 12.92 |
| C62 | 18.95 | 15.61 | 17.13 | 15.22 | 29.94 | 34.14 | 17.87 |
| C63 | 22.76 | 11.71 | 27.95 | 26.48 | 38.29 | 40 | 26.4 |

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|---|---|---|---|---|---|---|---|
| C64 | 18.27 | 7.49 | 27 | 25.34 | 38.33 | 40.73 | 25.98 |
| C65 | 18.91 | 12.02 | 19.19 | 17.38 | 31.4 | 34.72 | 18.86 |
| C66 | 6.71 | 9.98 | 29.43 | 27.52 | 42.25 | 46.42 | 30.14 |
| C67 | 12.72 | 12.76 | 23.58 | 21.68 | 36.42 | 40.77 | 24.51 |
| C68 | 14.67 | 5.93 | 25.33 | 23.52 | 37.45 | 40.55 | 24.91 |
| C69 | 11.65 | 7.66 | 25.13 | 23.24 | 37.78 | 41.52 | 25.37 |
| C70 | 20.15 | 9.3 | 32.88 | 31.29 | 43.71 | 45.63 | 31.59 |
| C71 | 3.77 | 12.05 | 33.25 | 31.34 | 46.08 | 50.36 | 34.08 |
| C72 | 11.49 | 4.93 | 26.84 | 24.97 | 39.29 | 42.72 | 26.77 |
| C73 | 34.45 | 28.14 | 5.33 | 4.91 | 15.3 | 18.54 | 2.97 |
| C74 | 38.14 | 29.24 | 15.62 | 15.55 | 20.25 | 20.29 | 12.43 |
| C75 | 43.8 | 34.8 | 18.32 | 18.79 | 19.11 | 17.49 | 15.05 |
| C76 | 29.88 | 22.79 | 10.15 | 8.89 | 20.85 | 23.67 | 8.54 |
| C77 | 29.01 | 23.79 | 7.41 | 5.58 | 19.96 | 23.98 | 7.7 |
| C78 | 33.06 | 23.46 | 18.47 | 17.74 | 25.84 | 26.55 | 15.8 |
| C79 | 31.85 | 22.98 | 15.3 | 14.47 | 23.6 | 24.97 | 12.8 |
| C80 | 33.2 | 22.92 | 22.23 | 21.45 | 29.41 | 29.77 | 19.58 |
| C81 | 42.47 | 32.69 | 21.87 | 21.95 | 24.3 | 22.8 | 18.61 |
| C82 | 40.82 | 30.52 | 24.54 | 24.33 | 28.34 | 27.12 | 21.4 |
| C83 | 36.97 | 26.31 | 25.91 | 25.33 | 31.66 | 31.17 | 23.03 |
| C84 | 29.2 | 21.16 | 13.27 | 12.08 | 23.29 | 25.55 | 11.37 |
| C85 | 33.58 | 25.4 | 12.3 | 11.7 | 20.21 | 21.77 | 9.57 |
| C86 | 35.72 | 25.33 | 23.45 | 22.84 | 29.58 | 29.4 | 20.6 |
| C87 | 51.94 | 45.95 | 16.09 | 17.95 | 3.71 | 2.7 | 15.3 |
| C88 | 37.21 | 35.85 | 11.95 | 12 | 18.78 | 24.82 | 15.23 |
| C89 | 54.61 | 47.02 | 21.12 | 22.67 | 12.16 | 6.58 | 18.99 |
| C90 | 31.58 | 28.39 | 6.36 | 5.11 | 18.33 | 23.54 | 9.1 |
| C91 | 40.52 | 37.15 | 7.47 | 8.65 | 11.52 | 17.52 | 10.22 |
| C92 | 46.66 | 39.96 | 12.15 | 13.76 | 6.38 | 6.52 | 10.25 |
| C93 | 56.48 | 48.09 | 25.03 | 26.37 | 17.54 | 12.12 | 22.47 |
| C94 | 38.21 | 32.19 | 4.3 | 5.41 | 11.23 | 14.73 | 1.59 |
| C95 | 37.88 | 33.08 | 1.88 | 3.75 | 11.12 | 16.06 | 4.06 |

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| C96 | 45.45 | 41.27 | 10.16 | 11.92 | 6.53 | 12.62 | 11.6 |
| C97 | 46.03 | 40.3 | 10.14 | 12.01 | 3.16 | 7.54 | 9.49 |
| C98 | 43.95 | 35.75 | 14.9 | 15.7 | 14.65 | 13.49 | 11.75 |
| C99 | 49.72 | 41.26 | 19.79 | 20.87 | 15.72 | 12.21 | 16.88 |
| C100 | 47.79 | 39.68 | 17.1 | 18.21 | 13.58 | 10.89 | 14.22 |
| C101 | 38.22 | 33.02 | 2.29 | 4.12 | 10.66 | 15.23 | 2.94 |
| C102 | 21.95 | 33 | 49.71 | 47.97 | 61.98 | 67.2 | 51.49 |
| C103 | 11.62 | 22.42 | 40.65 | 38.83 | 53.28 | 58.15 | 42.09 |
| C104 | 5.85 | 16.57 | 37.3 | 35.42 | 50.11 | 54.63 | 38.38 |
| C105 | 5.04 | 16.17 | 39.29 | 37.4 | 52.13 | 56.48 | 40.21 |
| C106 | 25.89 | 36.95 | 52.91 | 51.22 | 65.02 | 70.34 | 54.81 |
| C107 | 9.76 | 20.89 | 42.25 | 40.39 | 55.02 | 59.65 | 43.44 |
| C108 | 23.62 | 34.38 | 48.35 | 46.68 | 60.33 | 65.72 | 50.34 |
| C109 | 27.46 | 38.25 | 51.46 | 49.84 | 63.23 | 68.73 | 53.57 |
| C110 | 14.88 | 25.95 | 44.74 | 42.93 | 57.33 | 62.26 | 46.24 |
| C111 | 13.64 | 24.46 | 47.67 | 45.79 | 60.45 | 65.02 | 48.78 |
| C112 | 13.18 | 24.21 | 46.37 | 44.51 | 59.13 | 63.78 | 47.57 |
| C113 | 18.15 | 29.28 | 48.11 | 46.32 | 60.64 | 65.64 | 49.68 |
| C114 | 21.81 | 32.93 | 52.12 | 50.34 | 64.6 | 69.65 | 53.72 |
| C115 | 18.13 | 29.21 | 50 | 48.18 | 62.64 | 67.5 | 51.41 |
| C116 | 8.36 | 19.15 | 43.26 | 41.37 | 56.09 | 60.45 | 44.18 |
| C117 | 20.14 | 20.04 | 17.98 | 16.21 | 30.54 | 35.5 | 19.73 |
| C118 | 21.27 | 24.44 | 22.93 | 21.39 | 34.7 | 40.14 | 25.24 |
| C119 | 12.52 | 17.6 | 27.75 | 25.94 | 40.38 | 45.26 | 29.29 |
| C120 | 16.18 | 18.72 | 23.23 | 21.45 | 35.77 | 40.75 | 24.91 |
| C121 | 16.34 | 24.63 | 34.33 | 32.65 | 46.47 | 51.76 | 36.3 |
| C122 | 25.46 | 23.34 | 12.02 | 10.31 | 24.53 | 29.53 | 14 |
| C123 | 18.3 | 24.56 | 29.69 | 28.07 | 41.61 | 47.01 | 31.83 |
| C124 | 21.27 | 28.66 | 33.42 | 31.9 | 44.92 | 50.5 | 35.75 |
| C125 | 26.92 | 26.47 | 14.19 | 12.83 | 25.71 | 31.19 | 16.79 |
| C126 | 12.58 | 20.53 | 32.62 | 30.84 | 45.1 | 50.14 | 34.29 |
| C127 | 8.39 | 16.07 | 31.93 | 30.07 | 44.67 | 49.36 | 33.21 |

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| C128 | 15.11 | 24.86 | 38.25 | 36.52 | 50.57 | 55.75 | 40.05 |
| C129 | 29.4 | 37.58 | 40.08 | 38.77 | 50.52 | 56.39 | 42.75 |
| C130 | 27.8 | 32.31 | 27.08 | 25.91 | 37.24 | 43.12 | 29.91 |
| C131 | 24.72 | 28.12 | 23.43 | 22.09 | 34.43 | 40.12 | 26.06 |
| C132 | 28.77 | 34.86 | 32.37 | 31.18 | 42.44 | 48.35 | 35.17 |
| C133 | 30.09 | 30.3 | 15.34 | 14.36 | 25.48 | 31.28 | 18.33 |
| C134 | 31.63 | 38.81 | 37.64 | 36.49 | 47.43 | 53.39 | 40.48 |
| C135 | 30.24 | 39.15 | 43.54 | 42.2 | 54.14 | 59.98 | 46.15 |
| C136 | 30.31 | 33.04 | 22.54 | 21.58 | 32.04 | 37.99 | 25.55 |
| C137 | 36.44 | 39.15 | 24.81 | 24.28 | 32.2 | 38.28 | 28.04 |
| C138 | 34.42 | 38.49 | 28.35 | 27.57 | 36.68 | 42.74 | 31.47 |
| C139 | 33.65 | 34.69 | 18.34 | 17.73 | 26.73 | 32.75 | 21.53 |
| C140 | 40.31 | 43.71 | 29.29 | 28.9 | 35.63 | 41.72 | 32.56 |
| C141 | 38.07 | 38.86 | 19.3 | 19.12 | 25.6 | 31.69 | 22.59 |
| C142 | 24.83 | 32.24 | 34.92 | 33.52 | 45.89 | 51.63 | 37.46 |
| C143 | 40.04 | 42.16 | 24.76 | 24.53 | 30.62 | 36.7 | 28.05 |
| C144 | 33.9 | 39.04 | 31.67 | 30.78 | 40.4 | 46.45 | 34.73 |
| C145 | 23.8 | 32.62 | 39.31 | 37.81 | 50.65 | 56.29 | 41.67 |

| | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 | S9 | S10 | S11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C1 | 6.6 | 53.4 | 65.1 | 60.7 | 44.3 | 43.2 | 55.2 | 58.0 | 14.0 | 22.1 | 20.9 |
| C2 | 5.3 | 46.1 | 56.9 | 51.8 | 35.0 | 37.0 | 50.8 | 56.3 | 5.1 | 20.2 | 24.9 |
| C3 | 2.9 | 49.4 | 61.2 | 56.9 | 40.8 | 39.2 | 51.3 | 54.6 | 12.5 | 18.4 | 19.1 |
| C4 | 9.5 | 56.4 | 67.9 | 63.3 | 46.8 | 46.2 | 58.3 | 60.9 | 15.2 | 25.1 | 23.2 |
| C5 | 2.9 | 44.4 | 55.8 | 51.3 | 35.0 | 34.7 | 47.8 | 52.7 | 8.9 | 16.4 | 21.0 |
| C6 | 1.7 | 45.7 | 57.5 | 53.3 | 37.3 | 35.5 | 48.0 | 51.9 | 11.5 | 15.6 | 18.5 |
| C7 | 1.2 | 45.8 | 57.3 | 52.9 | 36.7 | 35.8 | 48.6 | 52.9 | 10.0 | 16.6 | 20.0 |
| C8 | 3.7 | 50.5 | 62.0 | 57.5 | 41.0 | 40.5 | 53.1 | 56.7 | 11.1 | 20.4 | 21.2 |
| C9 | 4.9 | 51.8 | 63.3 | 58.7 | 42.2 | 41.7 | 54.2 | 57.7 | 11.7 | 21.5 | 21.7 |
| C10 | 3.2 | 50.0 | 61.5 | 56.9 | 40.4 | 40.1 | 52.7 | 56.5 | 10.5 | 20.2 | 21.5 |
| C11 | 49.1 | 5.6 | 16.2 | 21.1 | 25.5 | 12.3 | 13.8 | 30.2 | 49.9 | 35.8 | 47.3 |
| C12 | 44.4 | 4.4 | 18.0 | 20.6 | 21.7 | 8.0 | 15.3 | 31.1 | 45.1 | 31.7 | 43.6 |
| C13 | 47.3 | 2.3 | 14.9 | 18.4 | 22.2 | 11.3 | 16.5 | 32.8 | 47.6 | 35.0 | 46.9 |
| C14 | 46.5 | 0.9 | 13.7 | 15.8 | 19.3 | 11.7 | 19.4 | 35.6 | 46.1 | 35.0 | 47.3 |
| C15 | 50.8 | 4.7 | 9.0 | 13.0 | 21.0 | 16.4 | 21.9 | 38.3 | 50.0 | 39.7 | 52.0 |
| C16 | 44.5 | 3.7 | 14.5 | 14.8 | 16.5 | 11.4 | 21.5 | 37.4 | 43.7 | 33.9 | 46.4 |
| C17 | 48.7 | 2.1 | 11.6 | 14.9 | 20.6 | 13.8 | 20.0 | 36.3 | 48.2 | 37.3 | 49.5 |
| C18 | 59.2 | 17.0 | 4.8 | 6.5 | 23.6 | 28.2 | 33.9 | 50.3 | 56.5 | 50.4 | 63.1 |
| C19 | 64.3 | 22.6 | 9.5 | 10.3 | 27.7 | 33.9 | 39.0 | 55.3 | 61.0 | 55.9 | 68.7 |
| C20 | 63.0 | 17.8 | 4.6 | 12.7 | 29.0 | 29.6 | 32.0 | 48.1 | 61.1 | 52.8 | 65.2 |
| C21 | 54.3 | 13.5 | 6.2 | 3.8 | 19.0 | 24.0 | 31.5 | 48.0 | 51.6 | 45.7 | 58.5 |
| C22 | 51.5 | 7.2 | 7.2 | 9.9 | 19.6 | 18.5 | 25.0 | 41.4 | 50.0 | 41.3 | 53.8 |
| C23 | 64.1 | 19.9 | 6.1 | 12.1 | 29.1 | 31.5 | 34.7 | 50.9 | 61.8 | 54.5 | 67.0 |
| C24 | 68.6 | 24.1 | 10.5 | 16.0 | 33.2 | 35.8 | 37.9 | 53.8 | 66.1 | 58.9 | 71.3 |
| C25 | 54.2 | 10.7 | 4.3 | 7.6 | 20.6 | 22.0 | 28.1 | 44.5 | 52.3 | 44.5 | 57.1 |
| C26 | 67.2 | 23.3 | 9.6 | 14.2 | 31.5 | 35.0 | 38.0 | 54.1 | 64.6 | 57.9 | 70.4 |
| C27 | 56.5 | 11.7 | 2.1 | 9.3 | 23.3 | 23.4 | 27.9 | 44.4 | 54.8 | 46.4 | 58.8 |
| C28 | 70.5 | 27.6 | 13.9 | 16.6 | 33.9 | 39.2 | 42.6 | 58.6 | 67.3 | 61.8 | 74.4 |
| C29 | 56.8 | 11.2 | 2.8 | 10.9 | 24.3 | 23.0 | 26.7 | 43.1 | 55.3 | 46.2 | 58.5 |
| C30 | 61.5 | 22.1 | 10.6 | 7.5 | 24.3 | 32.8 | 39.6 | 56.0 | 57.8 | 54.0 | 66.9 |
| C31 | 58.1 | 20.3 | 10.8 | 4.4 | 20.9 | 30.4 | 38.4 | 54.9 | 54.4 | 51.1 | 64.0 |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| C32 | 49.1 | 8.5 | 9.5 | 8.0 | 15.9 | 18.2 | 27.2 | 43.4 | 47.1 | 39.9 | 52.7 |
| C33 | 46.8 | 13.0 | 13.7 | 7.4 | 11.0 | 20.2 | 31.6 | 47.5 | 43.7 | 39.5 | 52.5 |
| C34 | 46.6 | 9.8 | 12.4 | 8.6 | 12.8 | 17.7 | 28.4 | 44.4 | 44.3 | 38.2 | 51.1 |
| C35 | 50.2 | 14.4 | 11.5 | 3.9 | 13.9 | 22.9 | 33.1 | 49.2 | 47.0 | 42.9 | 55.9 |
| C36 | 52.8 | 15.3 | 9.8 | 1.3 | 16.4 | 24.8 | 33.9 | 50.2 | 49.6 | 45.3 | 58.2 |
| C37 | 63.5 | 25.4 | 13.9 | 10.1 | 26.0 | 35.9 | 43.0 | 59.4 | 59.4 | 56.7 | 69.6 |
| C38 | 54.9 | 17.2 | 9.7 | 0.9 | 18.1 | 26.9 | 35.5 | 51.9 | 51.4 | 47.5 | 60.5 |
| C39 | 47.8 | 16.5 | 15.4 | 7.0 | 10.5 | 23.4 | 35.1 | 51.0 | 43.9 | 41.6 | 54.6 |
| C40 | 48.9 | 18.7 | 16.4 | 7.2 | 11.2 | 25.6 | 37.3 | 53.2 | 44.6 | 43.4 | 56.4 |
| C41 | 36.7 | 20.2 | 25.4 | 18.3 | 1.2 | 20.7 | 36.0 | 50.1 | 32.5 | 32.8 | 45.6 |
| C42 | 38.2 | 13.3 | 20.8 | 16.0 | 7.3 | 14.5 | 29.1 | 43.7 | 35.8 | 31.0 | 44.0 |
| C43 | 28.5 | 20.6 | 30.4 | 25.7 | 11.1 | 15.4 | 31.7 | 43.7 | 26.4 | 22.9 | 35.8 |
| C44 | 31.9 | 16.4 | 26.6 | 22.7 | 10.8 | 12.0 | 28.1 | 41.0 | 30.5 | 24.3 | 37.3 |
| C45 | 36.3 | 16.9 | 23.7 | 17.9 | 4.5 | 16.9 | 32.2 | 46.3 | 33.1 | 30.6 | 43.6 |
| C46 | 32.4 | 23.3 | 29.8 | 22.9 | 5.6 | 21.6 | 37.6 | 50.7 | 27.9 | 29.9 | 42.5 |
| C47 | 44.0 | 9.3 | 14.7 | 11.2 | 11.5 | 15.5 | 27.3 | 43.0 | 41.9 | 35.6 | 48.4 |
| C48 | 29.8 | 21.3 | 29.8 | 24.3 | 8.5 | 17.5 | 33.8 | 46.3 | 26.8 | 25.5 | 38.3 |
| C49 | 28.5 | 24.9 | 32.7 | 26.5 | 9.4 | 21.2 | 37.5 | 49.7 | 24.3 | 26.5 | 39.0 |
| C50 | 42.7 | 15.0 | 18.2 | 11.5 | 6.5 | 19.4 | 32.7 | 48.0 | 39.2 | 36.4 | 49.4 |
| C51 | 36.0 | 24.0 | 28.5 | 20.8 | 3.9 | 24.1 | 39.6 | 53.4 | 30.8 | 33.9 | 46.6 |
| C52 | 25.1 | 25.6 | 34.8 | 29.2 | 12.8 | 20.1 | 36.3 | 47.6 | 21.8 | 22.7 | 35.1 |
| C53 | 26.3 | 21.6 | 32.2 | 28.1 | 13.9 | 14.8 | 30.9 | 42.1 | 25.1 | 20.0 | 32.9 |
| C54 | 41.6 | 18.1 | 20.9 | 13.3 | 4.1 | 21.5 | 35.5 | 50.5 | 37.5 | 36.7 | 49.7 |
| C55 | 45.6 | 18.0 | 18.2 | 9.8 | 8.0 | 23.5 | 36.3 | 51.9 | 41.4 | 40.3 | 53.3 |
| C56 | 22.6 | 27.5 | 37.1 | 31.7 | 15.3 | 21.1 | 37.1 | 47.7 | 19.5 | 20.9 | 33.0 |
| C57 | 43.5 | 20.5 | 21.7 | 13.1 | 5.7 | 24.6 | 38.3 | 53.5 | 38.8 | 39.4 | 52.3 |
| C58 | 20.6 | 28.4 | 38.6 | 33.6 | 17.4 | 21.2 | 36.9 | 46.8 | 18.3 | 18.8 | 30.8 |
| C59 | 24.1 | 28.5 | 37.1 | 31.0 | 14.0 | 23.2 | 39.4 | 50.5 | 19.7 | 24.0 | 35.8 |
| C60 | 38.9 | 11.1 | 24.8 | 26.3 | 23.1 | 2.4 | 14.0 | 27.6 | 40.8 | 25.2 | 36.8 |
| C61 | 33.4 | 20.7 | 34.4 | 35.5 | 29.0 | 9.5 | 16.2 | 23.8 | 37.5 | 17.5 | 27.8 |
| C62 | 27.4 | 23.5 | 37.0 | 36.6 | 27.1 | 11.8 | 22.2 | 29.1 | 31.5 | 12.2 | 23.9 |
| C63 | 40.6 | 6.3 | 19.0 | 19.0 | 16.7 | 7.1 | 19.7 | 34.7 | 40.5 | 29.4 | 41.9 |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| C64 | 35.8 | 11.1 | 23.3 | 21.9 | 15.3 | 6.0 | 21.7 | 35.4 | 35.8 | 25.2 | 37.9 |
| C65 | 31.6 | 17.4 | 30.9 | 30.7 | 22.9 | 5.8 | 19.1 | 29.4 | 34.1 | 17.9 | 30.0 |
| C66 | 20.7 | 26.3 | 37.9 | 34.2 | 19.9 | 17.3 | 32.3 | 41.3 | 21.2 | 14.3 | 27.0 |
| C67 | 22.0 | 25.7 | 38.5 | 36.3 | 24.0 | 14.9 | 28.2 | 35.7 | 25.0 | 10.3 | 23.3 |
| C68 | 31.0 | 15.9 | 28.4 | 26.5 | 16.9 | 7.2 | 23.4 | 35.2 | 31.6 | 20.3 | 33.1 |
| C69 | 26.0 | 21.0 | 33.3 | 30.9 | 19.2 | 11.2 | 26.3 | 36.3 | 27.3 | 15.7 | 28.7 |
| C70 | 39.6 | 9.7 | 18.9 | 15.9 | 11.1 | 11.6 | 25.5 | 40.3 | 38.1 | 30.7 | 43.6 |
| C71 | 18.4 | 29.4 | 40.2 | 35.7 | 20.0 | 21.0 | 36.3 | 45.3 | 17.5 | 16.0 | 27.9 |
| C72 | 28.0 | 18.9 | 30.9 | 28.2 | 16.5 | 10.4 | 26.4 | 37.4 | 28.3 | 18.5 | 31.5 |
| C73 | 41.7 | 25.4 | 38.2 | 41.6 | 38.3 | 17.1 | 11.4 | 13.3 | 47.1 | 24.7 | 31.6 |
| C74 | 49.5 | 19.7 | 30.5 | 35.8 | 37.1 | 16.8 | 1.0 | 15.4 | 53.3 | 33.2 | 41.7 |
| C75 | 54.8 | 23.8 | 33.0 | 39.4 | 42.3 | 22.4 | 6.1 | 13.5 | 58.8 | 38.2 | 45.8 |
| C76 | 39.5 | 20.3 | 33.6 | 36.3 | 32.8 | 11.5 | 10.4 | 18.3 | 43.8 | 23.1 | 32.0 |
| C77 | 35.9 | 24.7 | 38.2 | 40.3 | 34.7 | 14.4 | 15.2 | 18.9 | 41.2 | 18.9 | 26.9 |
| C78 | 46.4 | 13.4 | 25.3 | 29.8 | 30.8 | 11.2 | 5.7 | 21.5 | 49.1 | 31.2 | 41.3 |
| C79 | 44.0 | 15.7 | 28.2 | 32.0 | 31.3 | 10.6 | 5.9 | 19.7 | 47.3 | 28.3 | 38.1 |
| C80 | 48.0 | 10.3 | 21.5 | 26.4 | 28.9 | 11.5 | 8.5 | 24.8 | 49.9 | 33.5 | 44.1 |
| C81 | 55.3 | 19.7 | 27.9 | 34.7 | 39.0 | 20.6 | 6.0 | 18.8 | 58.4 | 39.4 | 48.2 |
| C82 | 55.0 | 16.0 | 23.5 | 30.5 | 35.8 | 19.0 | 8.1 | 23.0 | 57.4 | 39.8 | 49.5 |
| C83 | 52.4 | 10.9 | 19.2 | 25.6 | 30.9 | 15.7 | 10.4 | 26.6 | 54.1 | 38.1 | 48.7 |
| C84 | 40.4 | 17.1 | 30.4 | 33.2 | 30.5 | 9.2 | 9.1 | 20.2 | 44.0 | 24.6 | 34.4 |
| C85 | 44.3 | 19.1 | 31.4 | 35.5 | 34.3 | 13.2 | 5.5 | 16.5 | 48.2 | 28.0 | 36.8 |
| C86 | 50.5 | 11.4 | 21.2 | 26.9 | 30.8 | 14.1 | 8.3 | 24.7 | 52.5 | 35.9 | 46.3 |
| C87 | 56.1 | 40.5 | 51.4 | 56.8 | 55.9 | 34.5 | 22.0 | 5.6 | 63.0 | 39.0 | 41.1 |
| C88 | 35.2 | 39.9 | 53.5 | 55.2 | 47.4 | 29.1 | 28.2 | 22.0 | 43.5 | 19.4 | 18.6 |
| C89 | 61.7 | 38.1 | 47.2 | 53.8 | 55.7 | 34.8 | 19.5 | 8.3 | 67.5 | 44.4 | 48.5 |
| C90 | 34.4 | 31.3 | 44.8 | 46.6 | 39.7 | 20.6 | 20.7 | 19.3 | 41.1 | 17.2 | 22.2 |
| C91 | 41.4 | 37.8 | 50.9 | 53.8 | 48.3 | 28.2 | 23.4 | 14.8 | 49.1 | 24.7 | 25.9 |
| C92 | 52.7 | 33.8 | 44.8 | 50.1 | 49.5 | 28.2 | 15.4 | 1.2 | 58.9 | 35.5 | 39.6 |
| C93 | 65.1 | 37.2 | 44.9 | 52.2 | 55.9 | 35.7 | 19.6 | 13.0 | 70.4 | 47.9 | 53.0 |
| C94 | 44.3 | 28.9 | 41.4 | 45.3 | 42.4 | 21.2 | 13.1 | 9.7 | 50.2 | 27.1 | 32.5 |
| C95 | 41.9 | 32.0 | 44.9 | 48.1 | 43.8 | 23.1 | 17.3 | 11.8 | 48.5 | 24.7 | 28.7 |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| C96 | 47.0 | 39.8 | 52.3 | 56.1 | 52.1 | 31.4 | 23.5 | 11.1 | 54.6 | 30.3 | 31.1 |
| C97 | 50.4 | 36.1 | 47.8 | 52.5 | 50.5 | 29.2 | 18.4 | 4.5 | 57.1 | 33.2 | 36.1 |
| C98 | 53.3 | 26.8 | 36.9 | 42.8 | 44.1 | 23.4 | 8.0 | 9.2 | 58.1 | 36.3 | 42.9 |
| C99 | 59.0 | 30.9 | 39.6 | 46.3 | 49.2 | 28.8 | 12.8 | 10.1 | 63.9 | 42.0 | 48.0 |
| C100 | 56.5 | 30.3 | 39.8 | 46.1 | 48.0 | 27.3 | 11.7 | 7.8 | 61.6 | 39.5 | 45.3 |
| C101 | 42.9 | 31.2 | 43.9 | 47.4 | 43.6 | 22.6 | 16.0 | 10.7 | 49.3 | 25.6 | 30.1 |
| C102 | 10.7 | 50.6 | 60.6 | 54.7 | 37.4 | 42.2 | 56.6 | 62.6 | 4.0 | 26.6 | 30.6 |
| C103 | 10.4 | 40.0 | 50.3 | 45.0 | 28.2 | 31.5 | 46.2 | 53.3 | 7.0 | 18.9 | 26.9 |
| C104 | 15.0 | 34.2 | 44.5 | 39.4 | 22.8 | 26.1 | 41.3 | 49.6 | 12.6 | 17.6 | 28.1 |
| C105 | 17.2 | 33.9 | 43.6 | 38.0 | 21.0 | 26.7 | 42.3 | 51.4 | 13.0 | 20.4 | 30.9 |
| C106 | 12.9 | 54.6 | 64.5 | 58.5 | 41.2 | 46.1 | 60.3 | 65.9 | 8.0 | 29.7 | 32.3 |
| C107 | 14.2 | 38.6 | 48.3 | 42.4 | 25.3 | 31.1 | 46.4 | 54.7 | 8.3 | 21.5 | 30.5 |
| C108 | 8.0 | 51.8 | 62.4 | 56.9 | 39.9 | 42.6 | 56.3 | 61.3 | 6.8 | 25.0 | 27.5 |
| C109 | 10.8 | 55.6 | 66.2 | 60.7 | 43.6 | 46.4 | 60.0 | 64.4 | 10.2 | 28.1 | 29.1 |
| C110 | 10.7 | 43.6 | 53.5 | 47.8 | 30.6 | 35.5 | 50.3 | 57.5 | 3.1 | 22.6 | 29.4 |
| C111 | 17.3 | 42.1 | 50.7 | 44.0 | 26.6 | 35.5 | 51.2 | 60.0 | 8.2 | 27.0 | 35.3 |
| C112 | 15.5 | 41.9 | 50.9 | 44.6 | 27.2 | 34.9 | 50.4 | 58.8 | 6.8 | 25.3 | 33.5 |
| C113 | 11.8 | 47.0 | 56.6 | 50.5 | 33.2 | 39.1 | 53.9 | 60.9 | 1.5 | 25.6 | 31.4 |
| C114 | 14.5 | 50.7 | 59.9 | 53.5 | 36.1 | 43.0 | 58.0 | 64.9 | 5.1 | 29.5 | 34.4 |
| C115 | 15.0 | 47.0 | 55.9 | 49.4 | 32.0 | 39.7 | 54.9 | 62.7 | 4.6 | 28.0 | 34.4 |
| C116 | 18.0 | 36.8 | 45.7 | 39.4 | 22.1 | 30.3 | 46.1 | 55.4 | 11.4 | 23.8 | 33.7 |
| C117 | 23.2 | 29.7 | 43.2 | 42.4 | 31.5 | 18.0 | 26.9 | 30.9 | 29.0 | 6.5 | 17.7 |
| C118 | 17.8 | 36.2 | 49.5 | 48.0 | 35.4 | 24.6 | 33.7 | 35.9 | 25.3 | 1.6 | 11.6 |
| C119 | 15.1 | 32.4 | 44.8 | 41.8 | 27.7 | 21.8 | 34.6 | 40.5 | 19.3 | 7.3 | 19.3 |
| C120 | 18.4 | 31.4 | 44.4 | 42.4 | 29.7 | 20.1 | 31.2 | 36.1 | 23.8 | 4.3 | 17.3 |
| C121 | 6.8 | 40.5 | 52.5 | 48.8 | 33.3 | 30.2 | 42.8 | 47.3 | 13.5 | 11.1 | 17.5 |
| C122 | 28.7 | 29.4 | 43.1 | 43.6 | 34.9 | 17.8 | 22.9 | 25.0 | 35.0 | 11.5 | 19.5 |
| C123 | 10.9 | 39.0 | 51.7 | 48.8 | 34.4 | 28.0 | 39.2 | 42.7 | 18.6 | 6.3 | 13.5 |
| C124 | 7.8 | 43.6 | 56.1 | 52.9 | 38.0 | 32.6 | 43.7 | 46.4 | 17.3 | 10.4 | 12.8 |
| C125 | 26.7 | 33.8 | 47.5 | 47.7 | 38.0 | 22.2 | 27.0 | 27.1 | 34.1 | 9.7 | 15.2 |
| C126 | 10.4 | 36.6 | 48.5 | 44.7 | 29.3 | 26.5 | 39.7 | 45.5 | 14.4 | 10.4 | 19.7 |
| C127 | 14.4 | 32.6 | 44.1 | 40.2 | 24.8 | 23.1 | 37.2 | 44.5 | 15.9 | 12.0 | 23.2 |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| C128 | 5.6 | 41.7 | 53.0 | 48.5 | 32.2 | 32.1 | 45.6 | 51.2 | 9.1 | 15.3 | 21.7 |
| C129 | 10.1 | 52.6 | 65.1 | 61.8 | 46.4 | 41.6 | 51.8 | 52.7 | 20.1 | 18.5 | 13.9 |
| C130 | 17.4 | 44.2 | 57.6 | 56.0 | 43.0 | 32.5 | 40.1 | 39.6 | 27.1 | 9.4 | 3.8 |
| C131 | 18.4 | 39.5 | 52.9 | 51.5 | 39.1 | 27.8 | 35.6 | 36.2 | 27.0 | 5.2 | 8.0 |
| C132 | 14.4 | 48.1 | 61.2 | 59.0 | 45.0 | 36.6 | 45.1 | 44.8 | 24.6 | 12.9 | 5.9 |
| C133 | 27.4 | 37.6 | 51.3 | 51.6 | 41.9 | 26.0 | 29.7 | 27.7 | 35.6 | 11.5 | 12.9 |
| C134 | 14.0 | 52.8 | 65.8 | 63.1 | 48.4 | 41.5 | 50.4 | 50.0 | 24.2 | 17.8 | 10.1 |
| C135 | 9.8 | 54.8 | 67.0 | 63.2 | 47.4 | 44.0 | 54.9 | 56.3 | 18.7 | 21.5 | 17.5 |
| C136 | 22.7 | 42.9 | 56.5 | 55.9 | 44.3 | 31.2 | 36.6 | 34.6 | 32.0 | 10.6 | 5.7 |
| C137 | 26.9 | 48.2 | 61.9 | 61.7 | 50.4 | 36.5 | 40.2 | 35.7 | 36.8 | 16.8 | 7.1 |
| C138 | 22.6 | 49.2 | 62.8 | 61.8 | 49.4 | 37.5 | 43.0 | 39.9 | 32.8 | 15.5 | 3.0 |
| C139 | 28.2 | 42.3 | 56.0 | 56.3 | 46.2 | 30.7 | 33.6 | 29.7 | 37.2 | 14.2 | 10.7 |
| C140 | 28.5 | 53.2 | 66.9 | 66.5 | 54.9 | 41.5 | 45.0 | 39.5 | 38.8 | 21.0 | 9.1 |
| C141 | 31.9 | 45.5 | 59.2 | 60.0 | 50.4 | 34.1 | 35.4 | 29.3 | 41.2 | 18.6 | 13.0 |
| C142 | 8.8 | 46.9 | 59.5 | 56.5 | 41.6 | 35.8 | 46.1 | 47.7 | 19.1 | 12.8 | 11.2 |
| C143 | 30.8 | 50.2 | 63.9 | 64.2 | 53.6 | 38.6 | 40.7 | 34.6 | 40.7 | 20.3 | 10.9 |
| C144 | 20.0 | 50.9 | 64.3 | 62.8 | 49.6 | 39.2 | 45.8 | 43.5 | 30.4 | 16.2 | 3.7 |
| C145 | 4.3 | 48.5 | 60.5 | 56.7 | 40.9 | 37.9 | 49.5 | 52.2 | 14.6 | 16.3 | 16.4 |

| | FM1 | FM2 | FM3 | FM4 | FM5 | FM6 | FM7 | FM8 | FM9 | FM10 | FM11 | FM12 | FM13 | FM14 | FM15 | FM16 | FM17 | FM18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **S1** | 48.6 | 44.6 | 54.2 | 44.0 | 46.9 | 53.9 | 51.6 | 47.2 | 45.8 | 52.3 | 56.8 | 37.8 | 19.0 | 8.8 | 6.7 | 29.4 | 31.7 | 19.5 |
| **S2** | 3.2 | 7.1 | 13.4 | 12.0 | 24.4 | 21.2 | 15.6 | 33.8 | 36.1 | 29.9 | 30.5 | 40.0 | 53.2 | 38.7 | 48.0 | 47.4 | 48.6 | 50.3 |
| **S3** | 14.4 | 20.2 | 6.4 | 24.8 | 36.2 | 30.4 | 25.2 | 46.0 | 48.5 | 40.7 | 40.0 | 53.4 | 61.7 | 50.8 | 60.4 | 61.2 | 62.3 | 63.7 |
| **S4** | 18.7 | 23.4 | 3.8 | 28.4 | 40.8 | 36.8 | 31.2 | 50.2 | 52.4 | 46.2 | 46.3 | 55.5 | 54.7 | 47.3 | 57.0 | 61.4 | 62.9 | 62.1 |
| **S5** | 23.4 | 24.4 | 18.8 | 28.3 | 39.8 | 39.9 | 34.6 | 47.5 | 48.7 | 46.3 | 48.2 | 48.5 | 37.4 | 32.1 | 41.6 | 50.9 | 52.7 | 48.9 |
| **S6** | 12.4 | 7.7 | 23.9 | 8.4 | 18.6 | 20.4 | 16.3 | 26.3 | 27.8 | 25.1 | 27.5 | 29.5 | 46.2 | 28.2 | 37.2 | 35.9 | 37.1 | 38.6 |
| **S7** | 16.2 | 12.3 | 31.5 | 8.2 | 7.2 | 4.4 | 4.7 | 17.0 | 19.8 | 11.4 | 12.0 | 27.2 | 61.5 | 40.7 | 48.1 | 38.4 | 38.7 | 45.3 |
| **S8** | 32.6 | 28.1 | 47.9 | 23.2 | 10.9 | 15.8 | 20.7 | 6.7 | 9.3 | 5.1 | 7.9 | 19.7 | 69.1 | 45.4 | 50.2 | 33.0 | 32.3 | 43.2 |
| **S9** | 49.0 | 45.9 | 51.5 | 46.5 | 51.8 | 57.5 | 54.4 | 53.8 | 52.9 | 57.8 | 61.9 | 46.0 | 9.5 | 15.0 | 17.0 | 39.1 | 41.4 | 29.8 |
| **S10** | 36.1 | 31.0 | 45.6 | 29.2 | 29.9 | 37.6 | 36.2 | 30.0 | 28.8 | 35.1 | 39.7 | 21.8 | 33.9 | 9.4 | 14.7 | 17.9 | 20.0 | 15.5 |
| **S11** | 47.9 | 42.4 | 58.4 | 39.7 | 37.0 | 45.9 | 45.7 | 33.5 | 31.2 | 40.6 | 45.5 | 21.3 | 39.0 | 17.2 | 13.7 | 9.9 | 12.1 | 3.2 |

| | FE1 | FE2 | FE3 | FE4 | FE5 | FE6 | FE7 |
|---|---|---|---|---|---|---|---|
| **S1** | 42.74 | 30.35 | 39.00 | 52.43 | 20.75 | 40.61 | 57.90 |
| **S2** | 28.27 | 17.75 | 29.20 | 39.18 | 28.88 | 30.40 | 39.94 |
| **S3** | 40.98 | 28.15 | 42.40 | 50.74 | 38.75 | 43.42 | 50.39 |
| **S4** | 44.54 | 24.26 | 45.15 | 55.57 | 33.52 | 46.48 | 56.14 |
| **S5** | 41.19 | 11.57 | 40.22 | 53.61 | 17.12 | 41.97 | 56.03 |
| **S6** | 20.05 | 12.44 | 19.69 | 32.33 | 21.91 | 21.26 | 34.71 |
| **S7** | 13.27 | 28.70 | 16.27 | 21.28 | 37.78 | 16.42 | 21.28 |
| **S8** | 11.26 | 41.12 | 14.66 | 5.75 | 47.76 | 12.99 | 5.35 |
| **S9** | 48.62 | 29.02 | 45.22 | 59.47 | 17.94 | 47.00 | 64.52 |
| **S10** | 25.52 | 23.00 | 21.75 | 35.37 | 19.72 | 23.36 | 40.71 |
| **S11** | 31.21 | 35.99 | 27.24 | 37.39 | 31.57 | 28.20 | 43.39 |

## Appendix G: Flooded area for wards at An Giang

| | | | Diện tích xã ứng với độ sâu ngập (ha) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Huyện** | **Xã** | **Diện tích xã (ha)** | Không ngập | <0.5m | 0.5-1m | 1-1.5m | 1.5-2m | 2-2.5m | 2.5-3m | 3-3.5m | >3.5m | Tổng |
| An Phú | Xã Vĩnh Lộc | 3632.9 | 13 | 13 | 22 | 58 | 83 | 51 | 1897 | 1442 | 53 | 3620 |
| An Phú | Xã Phú Hữu | 3625.3 | 30 | 22 | 31 | 80 | 134 | 779 | 1520 | 776 | 252 | 3595 |
| An Phú | Xã Phú Hội | 2392.9 | 18 | 22 | 37 | 52 | 63 | 224 | 403 | 815 | 758 | 2375 |
| An Phú | Xã Vĩnh Hậu | 2011.4 | 30 | 15 | 39 | 40 | 78 | 95 | 863 | 740 | 111 | 1981 |
| An Phú | Xã Đa Phước | 1573.5 | 29 | 24 | 32 | 56 | 72 | 60 | 593 | 442 | 266 | 1544 |
| An Phú | Xã Phước Hưng | 1520.8 | 41 | 37 | 46 | 71 | 200 | 462 | 355 | 94 | 216 | 1480 |
| An Phú | Xã Nhơn Hội | 1294.8 | 20 | 24 | 39 | 39 | 90 | 177 | 706 | 157 | 43 | 1275 |
| An Phú | Xã Vĩnh Trường | 1249.3 | 29 | 31 | 51 | 75 | 60 | 286 | 362 | 125 | 231 | 1220 |
| An Phú | Xã Quốc Thái | 1076.5 | 29 | 42 | 52 | 73 | 152 | 202 | 117 | 195 | 215 | 1047 |
| An Phú | Thị trấn An Phú | 815.0 | 31 | 44 | 44 | 34 | 51 | 242 | 227 | 48 | 93 | 784 |
| An Phú | Xã Khánh Bình | 797.5 | 7 | 36 | 40 | 39 | 36 | 157 | 161 | 64 | 258 | 791 |
| An Phú | Xã Vĩnh Hội Đông | 782.0 | 13 | 10 | 12 | 16 | 25 | 195 | 310 | 81 | 120 | 769 |
| An Phú | Khánh An | 630.3 | 14 | 13 | 52 | 87 | 85 | 51 | 115 | 78 | 136 | 617 |
| An Phú | Long Bình | 367.7 | 17 | 16 | 13 | 15 | 6 | 57 | 204 | 16 | 22 | 351 |
| Châu Đốc | Xã Vĩnh Tế | 3368.1 | 30 | 21 | 23 | 26 | 30 | 71 | 1134 | 2021 | 12 | 3338 |
| Châu Đốc | Xã Vĩnh Châu | 2276.9 | 223 | 95 | 119 | 139 | 181 | 270 | 1223 | 27 | | 2054 |
| Châu Đốc | Phường Núi Sam | 1391.6 | 274 | 43 | 58 | 82 | 118 | 218 | 373 | 226 | 0 | 1118 |
| Châu Đốc | Phường Châu Phú B | 1153.6 | 315 | 96 | 110 | 128 | 235 | 203 | 47 | 2 | 19 | 839 |
| Châu Đốc | Phường Vĩnh Ngươn | 945.8 | 23 | 21 | 27 | 25 | 24 | 135 | 481 | 80 | 129 | 922 |
| Châu Đốc | Phường Vĩnh Mỹ | 796.9 | 82 | 75 | 63 | 47 | 31 | 78 | 250 | 119 | 52 | 715 |
| Châu Đốc | Phường Châu Phú A | 523.4 | 82 | 36 | 15 | 18 | 15 | 22 | 196 | 122 | 19 | 442 |
| Châu Phú | Xã Ô Long Vỹ | 7254.1 | 12 | 26 | 25 | 37 | 63 | 243 | 6008 | 840 | | 7242 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Châu Phú | Xã Đào Hữu Cảnh | 5386.4 | 16 | 40 | 56 | 62 | 291 | 2851 | 2070 | 1 | | 5371 |
| Châu Phú | Xã Bình Phú | 4785.6 | 8 | 26 | 37 | 40 | 176 | 3460 | 1038 | 0 | | 4777 |
| Châu Phú | Xã Mỹ Đức | 3929.6 | 99 | 80 | 99 | 161 | 62 | 309 | 2648 | 473 | | 3831 |
| Châu Phú | Xã Mỹ Phú | 3641.9 | 20 | 85 | 98 | 75 | 44 | 713 | 2404 | 187 | 15 | 3621 |
| Châu Phú | Xã Thạnh Mỹ Tây | 3562.6 | 12 | 28 | 48 | 52 | 69 | 302 | 3024 | 28 | | 3551 |
| Châu Phú | Xã Bình Mỹ | 3506.5 | 57 | 125 | 109 | 66 | 612 | 2107 | 429 | 1 | | 3449 |
| Châu Phú | Xã Bình Chánh | 3178.9 | 0 | 3 | 11 | 22 | 84 | 1479 | 1580 | | | 3179 |
| Châu Phú | Xã Vĩnh Thạnh Trung | 2843.8 | 34 | 73 | 100 | 98 | 55 | 988 | 1405 | 90 | | 2810 |
| Châu Phú | Xã Bình Long | 2551.0 | 46 | 66 | 80 | 72 | 149 | 1403 | 711 | 25 | | 2505 |
| Châu Phú | Xã Khánh Hòa | 2209.1 | 30 | 142 | 133 | 102 | 185 | 1132 | 104 | 210 | 172 | 2179 |
| Châu Phú | Xã Bình Thủy | 1547.2 | 56 | 96 | 117 | 192 | 824 | 181 | 82 | | | 1492 |
| Châu Phú | Thị trấn Cái Dầu | 638.1 | 74 | 45 | 24 | 22 | 40 | 335 | 94 | 4 | | 565 |
| Châu Thành | Xã Vĩnh Bình | 4097.7 | 2 | 38 | 49 | 70 | 222 | 3665 | 53 | | | 4096 |
| Châu Thành | Xã Vĩnh Nhuận | 3801.3 | 42 | 61 | 71 | 111 | 1207 | 2309 | 1 | | | 3759 |
| Châu Thành | Xã Cần Đăng | 3747.4 | 10 | 52 | 126 | 120 | 159 | 3235 | 43 | 1 | | 3737 |
| Châu Thành | Xã Vĩnh Hanh | 3690.0 | 5 | 57 | 101 | 104 | 527 | 2788 | 109 | | | 3685 |
| Châu Thành | Xã Hòa Bình Thạnh | 3325.1 | 165 | 73 | 207 | 1857 | 777 | 245 | | | | 3160 |
| Châu Thành | Xã Vĩnh An | 3042.3 | 14 | 21 | 63 | 135 | 1714 | 1096 | 0 | | | 3028 |
| Châu Thành | Xã Vĩnh Lợi | 2635.7 | 31 | 30 | 54 | 729 | 1177 | 612 | 2 | | | 2605 |
| Châu Thành | Xã Vĩnh Thành | 2610.5 | 295 | 106 | 286 | 1849 | 75 | | | | | 2315 |
| Châu Thành | Xã Tân Phú | 2482.6 | 8 | 22 | 32 | 43 | 1130 | 1248 | | | | 2474 |
| Châu Thành | Xã Bình Hòa | 2226.3 | 246 | 88 | 140 | 361 | 890 | 496 | 3 | | | 1980 |
| Châu Thành | Xã An Hòa | 1680.3 | 121 | 81 | 97 | 320 | 468 | 591 | 2 | | | 1560 |
| Châu Thành | Thị trấn An Châu | 1284.5 | 381 | 48 | 403 | 380 | 72 | | | | | 903 |
| Châu Thành | Bình Thạnh | 865.5 | 70 | 275 | 160 | 354 | 6 | | | | | 795 |
| Chợ Mới | Xã An Thạnh Trung | 3213.7 | 237 | 166 | 1023 | 1435 | 352 | | | | | 2976 |
| Chợ Mới | Xã Nhơn Mỹ | 3045.0 | 585 | 101 | 886 | 1474 | | | | | | 2460 |
| Chợ Mới | Xã Mỹ Hội Đông | 2865.6 | 318 | 106 | 400 | 1450 | 521 | 40 | 31 | | | 2548 |
| Chợ Mới | Tấn Mỹ | 2721.1 | 79 | 210 | 273 | 307 | 908 | 622 | 322 | 1 | | 2642 |
| Chợ Mới | Xã Kiến An | 2524.4 | 136 | 229 | 372 | 687 | 955 | 73 | 71 | | | 2388 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chợ Mới | Mỹ Hiệp | 2321.1 | 35 | 69 | 140 | 447 | 1186 | 196 | 248 | 0 | | 2287 |
| Chợ Mới | Xã Hội An | 2311.3 | 204 | 210 | 750 | 923 | 224 | | | | | 2108 |
| Chợ Mới | Xã Kiến Thành | 2267.6 | 193 | 139 | 344 | 1338 | 247 | 6 | | | | 2074 |
| Chợ Mới | Xã Hòa Bình | 2224.0 | 458 | 424 | 1146 | 194 | 2 | | | | | 1766 |
| Chợ Mới | Bình Phước Xuân | 1891.2 | 91 | 123 | 234 | 1005 | 379 | 58 | 0 | | | 1800 |
| Chợ Mới | Xã Hòa An | 1880.5 | 412 | 279 | 1122 | 67 | | | | | | 1468 |
| Chợ Mới | Xã Long Giang | 1869.8 | 405 | 91 | 543 | 829 | 2 | | | | | 1465 |
| Chợ Mới | Xã Long Điền A | 1836.4 | 33 | 186 | 96 | 351 | 906 | 264 | | | | 1803 |
| Chợ Mới | Xã Long Điền B | 1786.6 | 104 | 108 | 75 | 527 | 960 | 13 | | | | 1682 |
| Chợ Mới | Xã Long Kiến | 1629.2 | 161 | 186 | 554 | 644 | 84 | | | | | 1468 |
| Chợ Mới | Xã Mỹ An | 1276.8 | 55 | 135 | 104 | 608 | 371 | 3 | 0 | | | 1222 |
| Chợ Mới | Thị trấn Mỹ Luông | 952.6 | 38 | 136 | 121 | 170 | 445 | 41 | 1 | | | 915 |
| Chợ Mới | Xã Chợ Mới | 307.0 | 29 | 85 | 52 | 30 | 90 | 20 | | | | 278 |
| Phú Tân | Xã Phú Thạnh | 2734.1 | 43 | 71 | 50 | 159 | 346 | 543 | 1490 | 19 | 13 | 2691 |
| Phú Tân | Xã Hoà Lạc | 2716.7 | 10 | 78 | 111 | 136 | 203 | 614 | 1457 | 82 | 26 | 2707 |
| Phú Tân | Xã Hiệp Xương | 2336.5 | 162 | 153 | 151 | 343 | 734 | 400 | 384 | 10 | | 2174 |
| Phú Tân | Xã Phú Bình | 2278.1 | 7 | 46 | 51 | 57 | 162 | 1127 | 739 | 84 | 4 | 2271 |
| Phú Tân | Xã Phú Thành | 2178.5 | 7 | 14 | 23 | 79 | 48 | 220 | 1696 | 89 | 2 | 2171 |
| Phú Tân | Xã Phú An | 2176.8 | 36 | 57 | 79 | 61 | 281 | 898 | 438 | 327 | | 2141 |
| Phú Tân | Xã Phú Hiệp | 1845.6 | 11 | 16 | 56 | 87 | 193 | 290 | 807 | 214 | 170 | 1834 |
| Phú Tân | Xã Phú Xuân | 1834.1 | 14 | 26 | 56 | 114 | 401 | 748 | 461 | 14 | 0 | 1820 |
| Phú Tân | Xã Phú Thọ | 1766.8 | 9 | 33 | 38 | 24 | 515 | 809 | 180 | 158 | | 1758 |
| Phú Tân | Xã Phú Long | 1744.7 | 12 | 8 | 52 | 107 | 216 | 699 | 599 | 50 | 2 | 1733 |
| Phú Tân | Thị trấn Chợ Vàm | 1705.3 | 47 | 121 | 68 | 75 | 249 | 546 | 423 | 147 | 30 | 1658 |
| Phú Tân | Xã Phú Hưng | 1577.4 | 31 | 56 | 71 | 61 | 1021 | 316 | 17 | 4 | | 1546 |
| Phú Tân | Xã Bình Thạnh Đông | 1562.7 | 47 | 52 | 106 | 153 | 699 | 176 | 260 | 67 | 2 | 1515 |
| Phú Tân | Xã Phú Lâm | 1507.6 | 41 | 55 | 96 | 33 | 171 | 782 | 224 | 9 | 97 | 1466 |
| Phú Tân | Phường Long Sơn | 1353.0 | 44 | 54 | 78 | 27 | 44 | 359 | 461 | 185 | 101 | 1309 |
| Phú Tân | Xã Tân Hòa | 994.8 | 50 | 33 | 33 | 96 | 690 | 51 | 13 | 28 | | 945 |
| Phú Tân | Xã Long Hoà | 837.9 | 51 | 51 | 33 | 11 | 7 | 315 | 337 | 7 | 26 | 787 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Phú Tân | Xã Tân Trung | 819.6 | 42 | 38 | 41 | 133 | 163 | 130 | 251 | 23 | | 778 |
| Phú Tân | Thị trấn Phú Mỹ | 777.4 | 123 | 74 | 39 | 179 | 163 | 17 | 183 | | | 654 |
| Tân Châu | Xã Phú Lộc | 2331.4 | 31 | 11 | 13 | 12 | 36 | 48 | 675 | 1408 | 97 | 2300 |
| Tân Châu | Xã Vĩnh Hòa | 2115.8 | 97 | 64 | 83 | 142 | 237 | 347 | 294 | 134 | 718 | 2019 |
| Tân Châu | Xã Châu Phong | 1778.1 | 35 | 25 | 21 | 25 | 15 | 139 | 701 | 798 | 20 | 1744 |
| Tân Châu | Xã Phú Vĩnh | 1770.5 | 24 | 46 | 43 | 34 | 165 | 812 | 592 | 30 | 23 | 1747 |
| Tân Châu | Xã Lê Chánh | 1685.2 | 8 | 10 | 16 | 18 | 25 | 82 | 490 | 1014 | 21 | 1677 |
| Tân Châu | Xã Long An | 1493.6 | 54 | 21 | 13 | 20 | 435 | 600 | 193 | 78 | 81 | 1439 |
| Tân Châu | Xã Tân An | 1477.5 | 63 | 43 | 73 | 143 | 220 | 240 | 266 | 229 | 201 | 1415 |
| Tân Châu | Xã Vĩnh Xương | 1417.9 | 156 | 108 | 95 | 52 | 56 | 250 | 299 | 182 | 220 | 1261 |
| Tân Châu | Xã Tân Thạnh | 1224.9 | 26 | 46 | 30 | 97 | 231 | 336 | 386 | 60 | 13 | 1199 |
| Tân Châu | Phường Long Phú | 1048.3 | 7 | 70 | 21 | 16 | 27 | 191 | 568 | 134 | 14 | 1042 |
| Tân Châu | Tân Châu | 676.5 | 31 | 89 | 87 | 44 | 132 | 157 | 69 | 4 | 65 | 646 |
| Thoại Sơn | Xã Vĩnh Chánh | 3832.7 | 111 | 168 | 3258 | 296 | | | | | | 3722 |
| Thoại Sơn | Xã Định Mỹ | 3706.7 | 197 | 240 | 1249 | 1984 | 37 | | | | | 3510 |
| Thoại Sơn | Xã Vĩnh Phú | 3669.0 | 35 | 57 | 90 | 626 | 2272 | 588 | | | | 3634 |
| Thoại Sơn | Xã Định Thành | 3534.9 | 124 | 126 | 1282 | 1971 | 31 | | | | | 3410 |
| Thoại Sơn | Xã Tây Phú | 3475.6 | 29 | 35 | 50 | 152 | 2879 | 330 | | | | 3446 |
| Thoại Sơn | Xã Vĩnh Khánh | 3283.9 | 200 | 122 | 2101 | 861 | | | | | | 3084 |
| Thoại Sơn | Xã Phú Thuận | 3127.4 | 173 | 152 | 2558 | 245 | | | | | | 2954 |
| Thoại Sơn | Xã Mỹ Phú Đông | 3083.6 | 37 | 62 | 141 | 1949 | 894 | | | | | 3046 |
| Thoại Sơn | Xã Vọng Đông | 2966.8 | 140 | 284 | 608 | 1805 | 130 | 0 | | | | 2827 |
| Thoại Sơn | Xã Thoại Giang | 2932.7 | 202 | 143 | 619 | 1900 | 69 | | | | | 2731 |
| Thoại Sơn | Xã An Bình | 2798.6 | 18 | 51 | 135 | 960 | 1634 | 0 | | | | 2781 |
| Thoại Sơn | Xã Bình Thành | 2721.3 | 139 | 197 | 1446 | 939 | | | | | | 2583 |
| Thoại Sơn | Xã Vọng Thê | 2716.6 | 36 | 72 | 81 | 785 | 1744 | 0 | | | | 2681 |
| Thoại Sơn | Xã Vĩnh Trạch | 2072.2 | 293 | 159 | 370 | 1249 | 2 | | | | | 1780 |
| Thoại Sơn | Thị Trấn Óc Eo | 1207.4 | 404 | 45 | 53 | 567 | 138 | | | | | 803 |
| Thoại Sơn | Thị trấn Núi Sập | 955.2 | 241 | 45 | 182 | 487 | | | | | | 714 |
| Thoại Sơn | Thị trấn Phú Hoà | 721.9 | 152 | 68 | 420 | 82 | | | | | | 570 |
| Tịnh Biên | Xã An Hảo | 5338.0 | 3710 | 55 | 83 | 102 | 1031 | 357 | | | | 1628 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tịnh Biên | Xã An Cư | 4226.1 | 4222 | 4 | | | | | | | | 4 |
| Tịnh Biên | Xã An Nông | 3248.1 | 984 | 95 | 97 | 105 | 788 | 1102 | 59 | 18 | 0 | 2264 |
| Tịnh Biên | Xã Tân Lợi | 3091.4 | 1114 | 35 | 44 | 62 | 161 | 844 | 747 | 84 | 0 | 1977 |
| Tịnh Biên | Xã Tân Lập | 3003.3 | 57 | 39 | 29 | 36 | 1412 | 1427 | 3 | | | 2946 |
| Tịnh Biên | Xã Văn Giáo | 2709.5 | 585 | 46 | 57 | 30 | 71 | 516 | 1388 | 16 | | 2124 |
| Tịnh Biên | Xã Vĩnh Trung | 2482.4 | 786 | 40 | 52 | 86 | 55 | 238 | 1223 | 2 | | 1697 |
| Tịnh Biên | Xã Thới Sơn | 2430.3 | 865 | 6 | 18 | 20 | 60 | 161 | 862 | 439 | | 1565 |
| Tịnh Biên | Thị trấn Tịnh Biên | 2177.2 | 1326 | 61 | 60 | 65 | 63 | 77 | 140 | 359 | 27 | 852 |
| Tịnh Biên | Xã An Phú | 2162.8 | 1599 | 22 | 18 | 20 | 25 | 16 | 26 | 274 | 163 | 564 |
| Tịnh Biên | Xã Nhơn Hưng | 1965.3 | 188 | 18 | 18 | 21 | 22 | 41 | 98 | 1375 | 185 | 1777 |
| Tịnh Biên | Xã Núi Voi | 1406.4 | 103 | 8 | 16 | 38 | 63 | 117 | 1049 | 12 | | 1304 |
| Tịnh Biên | Thị trấn Chi Lăng | 668.9 | 661 | 4 | 3 | 0 | | | | | | 8 |
| Tịnh Biên | Thị trấn Nhà Bàng | 593.9 | 417 | 8 | 6 | 6 | 7 | 20 | 59 | 70 | | 176 |
| TP. Long Xuyên | Phường Mỹ Thới | 2131.5 | 313 | 174 | 1525 | 114 | 5 | | | | | 1818 |
| TP. Long Xuyên | Xã Mỹ Hoà Hưng | 2117.7 | 611 | 229 | 487 | 517 | 274 | | | | | 1507 |
| TP. Long Xuyên | Phường Mỹ Hòa | 1646.1 | 380 | 125 | 1018 | 113 | 10 | | | | | 1266 |
| TP. Long Xuyên | Phường Mỹ Thạnh | 1509.8 | 393 | 74 | 954 | 80 | 9 | | | | | 1117 |
| TP. Long Xuyên | Phường Bình Đức | 1155.2 | 274 | 47 | 428 | 326 | 80 | | | | | 882 |
| TP. Long Xuyên | Xã Mỹ Khánh | 950.3 | 216 | 50 | 420 | 260 | 4 | | | | | 735 |
| TP. Long Xuyên | Phường Bình Khánh | 663.6 | 233 | 19 | 303 | 72 | 38 | | | | | 431 |
| TP. Long Xuyên | Phường Mỹ Phước | 429.1 | 227 | 22 | 113 | 62 | 5 | | | | | 202 |
| TP. Long Xuyên | Phường Mỹ Quý | 418.9 | 165 | 23 | 187 | 43 | 0 | | | | | 254 |
| TP. Long Xuyên | Mỹ Bình | 160.9 | 110 | 2 | 2 | 5 | 42 | | | | | 51 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TP. Long Xuyên | Mỹ Long | 123.4 | 73 | 7 | 4 | 29 | 10 | | | | | 50 |
| TP. Long Xuyên | Phường Đông Xuyên | 119.5 | 109 | 1 | 8 | 0 | 1 | | | | | 11 |
| TP. Long Xuyên | Mỹ Xuyên | 61.6 | 61 | 0 | 0 | 0 | | | | | | 1 |
| Tri Tôn | Xã Lương An Trà | 8862.7 | 74 | 147 | 299 | 4145 | 4003 | 192 | 4 | | | 8789 |
| Tri Tôn | Xã Tân Tuyến | 8352.0 | 18 | 57 | 71 | 1225 | 6741 | 239 | | | | 8334 |
| Tri Tôn | Xã Vĩnh Phước | 5428.1 | 31 | 31 | 75 | 212 | 2993 | 2067 | 19 | | | 5397 |
| Tri Tôn | Xã Tà Đảnh | 5012.3 | 8 | 14 | 36 | 147 | 4622 | 185 | | | | 5004 |
| Tri Tôn | Xã Cô Tô | 4243.1 | 740 | 89 | 129 | 378 | 2834 | 73 | | | | 3503 |
| Tri Tôn | Xã Lương Phi | 4116.5 | 1893 | 130 | 314 | 563 | 1182 | 35 | | | | 2224 |
| Tri Tôn | Xã Vĩnh Gia | 3803.2 | 74 | 34 | 76 | 1257 | 2253 | 97 | 13 | | | 3729 |
| Tri Tôn | Xã Châu Lăng | 3254.8 | 1570 | 194 | 217 | 251 | 1013 | 10 | | | | 1685 |
| Tri Tôn | Xã Núi Tô | 3250.0 | 1490 | 89 | 121 | 167 | 1361 | 23 | | | | 1760 |
| Tri Tôn | Xã Ô Lâm | 3006.1 | 1451 | 152 | 275 | 1069 | 56 | 4 | | | | 1556 |
| Tri Tôn | Xã An Tức | 2789.5 | 971 | 61 | 135 | 532 | 1086 | 2 | 2 | 1 | | 1818 |
| Tri Tôn | Xã Lê Trì | 2666.2 | 1839 | 121 | 122 | 159 | 291 | 127 | 5 | 1 | | 827 |
| Tri Tôn | Xã Lạc Quới | 2466.1 | 63 | 52 | 35 | 73 | 1691 | 505 | 45 | 2 | | 2403 |
| Tri Tôn | Thị trấn Ba Chúc | 1909.7 | 1388 | 89 | 123 | 139 | 155 | 16 | 1 | | | 522 |
| Tri Tôn | Thị trấn Tri Tôn | 817.6 | 226 | 30 | 74 | 103 | 384 | 1 | | | | 592 |

## Appendix H: Sequence of storages (for serving fields) and facilities (for serving storages) in the case study

| | Storage sequence (S) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **C1** | 1 | 11 | 10 | 9 | 6 | 8 | 7 | 4 | 5 | 3 | 2 |
| **C2** | 9 | 11 | 10 | 1 | 6 | 8 | 5 | 3 | 7 | 2 | 4 |
| **C3** | 1 | 11 | 10 | 9 | 6 | 8 | 7 | 4 | 5 | 2 | 3 |
| **C4** | 1 | 11 | 10 | 9 | 6 | 8 | 7 | 4 | 5 | 3 | 2 |
| **C5** | 1 | 11 | 10 | 9 | 6 | 8 | 5 | 4 | 7 | 2 | 3 |
| **C6** | 1 | 11 | 10 | 9 | 6 | 8 | 7 | 4 | 5 | 2 | 3 |
| **C7** | 1 | 11 | 10 | 9 | 6 | 8 | 5 | 4 | 7 | 2 | 3 |
| **C8** | 1 | 11 | 10 | 9 | 6 | 8 | 7 | 4 | 5 | 2 | 3 |
| **C9** | 1 | 11 | 10 | 9 | 6 | 8 | 7 | 4 | 5 | 2 | 3 |
| **C10** | 1 | 11 | 10 | 9 | 6 | 8 | 7 | 4 | 5 | 2 | 3 |
| **C11** | 11 | 1 | 6 | 5 | 2 | 4 | 3 | 7 | 10 | 9 | 8 |
| **C12** | 11 | 1 | 6 | 5 | 2 | 4 | 3 | 7 | 10 | 9 | 8 |
| **C13** | 11 | 1 | 5 | 6 | 2 | 4 | 3 | 7 | 10 | 9 | 8 |
| **C14** | 10 | 1 | 5 | 2 | 3 | 4 | 6 | 9 | 7 | 8 | 11 |
| **C15** | 10 | 1 | 2 | 3 | 5 | 4 | 6 | 7 | 9 | 8 | 11 |
| **C16** | 10 | 1 | 5 | 2 | 3 | 4 | 6 | 9 | 7 | 8 | 11 |
| **C17** | 10 | 1 | 2 | 5 | 6 | 4 | 3 | 7 | 9 | 8 | 11 |
| **C18** | 10 | 3 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 8 | 11 |
| **C19** | 10 | 3 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 8 | 11 |
| **C20** | 10 | 3 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 8 | 11 |
| **C21** | 10 | 3 | 2 | 1 | 4 | 5 | 6 | 9 | 7 | 8 | 11 |
| **C22** | 10 | 2 | 1 | 3 | 5 | 4 | 6 | 9 | 7 | 8 | 11 |
| **C23** | 10 | 3 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 8 | 11 |
| **C24** | 10 | 3 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 8 | 11 |
| **C25** | 10 | 3 | 1 | 2 | 4 | 5 | 6 | 9 | 7 | 8 | 11 |
| **C26** | 10 | 3 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 8 | 11 |
| **C27** | 10 | 3 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 8 | 11 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **C28** | 10 | 3 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 8 | 11 |
| **C29** | 10 | 3 | 1 | 2 | 5 | 4 | 6 | 7 | 9 | 8 | 11 |
| **C30** | 10 | 3 | 2 | 1 | 4 | 5 | 6 | 9 | 7 | 8 | 11 |
| **C31** | 10 | 3 | 2 | 1 | 4 | 5 | 6 | 9 | 8 | 7 | 11 |
| **C32** | 10 | 3 | 1 | 2 | 4 | 5 | 6 | 9 | 7 | 8 | 11 |
| **C33** | 10 | 4 | 3 | 2 | 1 | 5 | 6 | 9 | 7 | 8 | 11 |
| **C34** | 10 | 3 | 1 | 2 | 4 | 5 | 6 | 9 | 8 | 7 | 11 |
| **C35** | 10 | 4 | 2 | 1 | 3 | 5 | 6 | 9 | 8 | 7 | 11 |
| **C36** | 10 | 3 | 2 | 1 | 4 | 5 | 6 | 9 | 8 | 7 | 11 |
| **C37** | 10 | 3 | 2 | 1 | 4 | 5 | 6 | 9 | 8 | 7 | 11 |
| **C38** | 10 | 3 | 2 | 1 | 4 | 5 | 6 | 9 | 8 | 7 | 11 |
| **C39** | 10 | 4 | 3 | 1 | 2 | 5 | 6 | 9 | 7 | 8 | 11 |
| **C40** | 10 | 4 | 3 | 1 | 2 | 5 | 6 | 9 | 7 | 8 | 11 |
| **C41** | 10 | 4 | 5 | 1 | 2 | 3 | 9 | 11 | 8 | 6 | 7 |
| **C42** | 10 | 4 | 5 | 1 | 2 | 3 | 6 | 9 | 7 | 8 | 11 |
| **C43** | 10 | 5 | 9 | 6 | 3 | 2 | 1 | 11 | 7 | 8 | 4 |
| **C44** | 10 | 5 | 9 | 1 | 2 | 3 | 4 | 11 | 7 | 8 | 6 |
| **C45** | 10 | 4 | 5 | 1 | 2 | 3 | 9 | 11 | 7 | 8 | 6 |
| **C46** | 10 | 5 | 6 | 3 | 2 | 1 | 9 | 11 | 8 | 7 | 4 |
| **C47** | 10 | 1 | 4 | 2 | 3 | 5 | 6 | 9 | 8 | 7 | 11 |
| **C48** | 10 | 5 | 9 | 1 | 2 | 3 | 6 | 11 | 7 | 8 | 4 |
| **C49** | 10 | 6 | 9 | 4 | 3 | 2 | 5 | 11 | 8 | 7 | 1 |
| **C50** | 10 | 4 | 3 | 1 | 2 | 5 | 6 | 9 | 7 | 8 | 11 |
| **C51** | 10 | 4 | 5 | 1 | 2 | 3 | 9 | 11 | 8 | 7 | 6 |
| **C52** | 10 | 9 | 6 | 5 | 3 | 4 | 11 | 1 | 8 | 7 | 2 |
| **C53** | 10 | 9 | 5 | 6 | 3 | 4 | 7 | 11 | 2 | 8 | 1 |
| **C54** | 10 | 4 | 3 | 1 | 2 | 5 | 6 | 11 | 7 | 8 | 9 |
| **C55** | 10 | 4 | 3 | 1 | 2 | 5 | 6 | 9 | 7 | 8 | 11 |
| **C56** | 10 | 9 | 11 | 5 | 3 | 1 | 6 | 2 | 8 | 7 | 4 |
| **C57** | 10 | 4 | 3 | 1 | 2 | 5 | 6 | 11 | 8 | 7 | 9 |
| **C58** | 10 | 9 | 11 | 5 | 3 | 7 | 6 | 2 | 8 | 1 | 4 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **C59** | 10 | 9 | 11 | 5 | 3 | 2 | 6 | 1 | 8 | 7 | 4 |
| **C60** | 11 | 5 | 6 | 8 | 4 | 3 | 2 | 1 | 10 | 9 | 7 |
| **C61** | 11 | 8 | 10 | 6 | 7 | 4 | 3 | 1 | 5 | 9 | 2 |
| **C62** | 11 | 7 | 10 | 6 | 9 | 3 | 2 | 8 | 4 | 5 | 1 |
| **C63** | 10 | 1 | 5 | 4 | 3 | 2 | 6 | 9 | 7 | 8 | 11 |
| **C64** | 10 | 5 | 6 | 1 | 3 | 2 | 4 | 9 | 7 | 8 | 11 |
| **C65** | 11 | 5 | 10 | 8 | 6 | 2 | 4 | 3 | 7 | 9 | 1 |
| **C66** | 10 | 6 | 11 | 9 | 7 | 4 | 5 | 3 | 2 | 8 | 1 |
| **C67** | 10 | 11 | 6 | 9 | 1 | 4 | 8 | 3 | 7 | 5 | 2 |
| **C68** | 10 | 5 | 7 | 6 | 3 | 2 | 1 | 11 | 9 | 8 | 4 |
| **C69** | 10 | 6 | 11 | 5 | 7 | 3 | 4 | 9 | 2 | 8 | 1 |
| **C70** | 10 | 1 | 5 | 4 | 2 | 3 | 6 | 9 | 7 | 8 | 11 |
| **C71** | 10 | 11 | 9 | 1 | 7 | 2 | 6 | 3 | 5 | 8 | 4 |
| **C72** | 10 | 7 | 5 | 9 | 4 | 3 | 2 | 11 | 6 | 8 | 1 |
| **C73** | 11 | 8 | 10 | 7 | 6 | 2 | 3 | 4 | 5 | 9 | 1 |
| **C74** | 11 | 7 | 6 | 8 | 5 | 2 | 4 | 3 | 10 | 9 | 1 |
| **C75** | 11 | 7 | 6 | 8 | 5 | 2 | 4 | 3 | 10 | 9 | 1 |
| **C76** | 11 | 7 | 10 | 8 | 6 | 2 | 3 | 4 | 5 | 9 | 1 |
| **C77** | 11 | 8 | 10 | 7 | 6 | 4 | 3 | 1 | 5 | 9 | 2 |
| **C78** | 11 | 6 | 7 | 5 | 1 | 3 | 4 | 2 | 10 | 9 | 8 |
| **C79** | 11 | 6 | 7 | 8 | 5 | 4 | 3 | 2 | 10 | 9 | 1 |
| **C80** | 11 | 6 | 1 | 7 | 5 | 3 | 4 | 2 | 10 | 9 | 8 |
| **C81** | 11 | 7 | 6 | 1 | 5 | 2 | 4 | 3 | 10 | 9 | 8 |
| **C82** | 11 | 6 | 7 | 1 | 5 | 3 | 4 | 2 | 10 | 9 | 8 |
| **C83** | 11 | 6 | 1 | 5 | 7 | 3 | 4 | 2 | 10 | 9 | 8 |
| **C84** | 11 | 6 | 8 | 7 | 5 | 4 | 3 | 2 | 10 | 9 | 1 |
| **C85** | 11 | 7 | 8 | 6 | 5 | 4 | 3 | 2 | 10 | 9 | 1 |
| **C86** | 11 | 6 | 1 | 7 | 5 | 3 | 4 | 2 | 10 | 9 | 8 |
| **C87** | 11 | 8 | 10 | 7 | 6 | 2 | 3 | 4 | 5 | 9 | 1 |
| **C88** | 11 | 10 | 8 | 7 | 9 | 6 | 1 | 5 | 3 | 4 | 2 |
| **C89** | 11 | 7 | 8 | 10 | 6 | 2 | 3 | 4 | 5 | 9 | 1 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **C90** | 11 | 10 | 8 | 7 | 9 | 1 | 5 | 4 | 6 | 2 | 3 |
| **C91** | 11 | 10 | 8 | 7 | 9 | 6 | 3 | 4 | 1 | 2 | 5 |
| **C92** | 11 | 7 | 10 | 8 | 6 | 2 | 4 | 3 | 5 | 9 | 1 |
| **C93** | 11 | 7 | 6 | 8 | 10 | 2 | 3 | 4 | 5 | 9 | 1 |
| **C94** | 11 | 8 | 10 | 7 | 6 | 2 | 3 | 4 | 5 | 9 | 1 |
| **C95** | 11 | 10 | 8 | 7 | 6 | 5 | 3 | 4 | 2 | 9 | 1 |
| **C96** | 11 | 10 | 8 | 7 | 6 | 9 | 3 | 4 | 1 | 2 | 5 |
| **C97** | 11 | 8 | 10 | 7 | 6 | 2 | 5 | 4 | 3 | 9 | 1 |
| **C98** | 11 | 7 | 8 | 6 | 10 | 2 | 4 | 3 | 5 | 9 | 1 |
| **C99** | 11 | 7 | 6 | 8 | 10 | 2 | 3 | 4 | 5 | 9 | 1 |
| **C100** | 11 | 7 | 8 | 10 | 6 | 2 | 3 | 4 | 5 | 9 | 1 |
| **C101** | 11 | 10 | 8 | 7 | 6 | 5 | 3 | 4 | 2 | 9 | 1 |
| **C102** | 9 | 11 | 10 | 1 | 6 | 7 | 2 | 3 | 8 | 5 | 4 |
| **C103** | 9 | 11 | 10 | 1 | 6 | 7 | 2 | 3 | 8 | 5 | 4 |
| **C104** | 9 | 11 | 10 | 1 | 7 | 2 | 6 | 3 | 8 | 5 | 4 |
| **C105** | 9 | 11 | 10 | 1 | 7 | 2 | 6 | 3 | 8 | 5 | 4 |
| **C106** | 9 | 11 | 10 | 1 | 6 | 7 | 2 | 3 | 8 | 5 | 4 |
| **C107** | 9 | 11 | 10 | 1 | 7 | 6 | 2 | 3 | 8 | 5 | 4 |
| **C108** | 9 | 11 | 10 | 1 | 6 | 8 | 5 | 3 | 7 | 2 | 4 |
| **C109** | 9 | 11 | 10 | 1 | 6 | 8 | 5 | 3 | 7 | 2 | 4 |
| **C110** | 9 | 11 | 10 | 1 | 6 | 7 | 2 | 3 | 8 | 5 | 4 |
| **C111** | 9 | 11 | 10 | 1 | 2 | 6 | 5 | 3 | 8 | 7 | 4 |
| **C112** | 9 | 11 | 10 | 1 | 7 | 6 | 2 | 3 | 8 | 5 | 4 |
| **C113** | 9 | 11 | 10 | 1 | 6 | 7 | 2 | 3 | 8 | 5 | 4 |
| **C114** | 9 | 11 | 10 | 1 | 6 | 7 | 2 | 3 | 8 | 5 | 4 |
| **C115** | 9 | 11 | 10 | 1 | 7 | 6 | 2 | 3 | 8 | 5 | 4 |
| **C116** | 9 | 11 | 10 | 1 | 2 | 5 | 6 | 3 | 8 | 7 | 4 |
| **C117** | 11 | 10 | 6 | 9 | 7 | 8 | 1 | 3 | 4 | 5 | 2 |
| **C118** | 11 | 10 | 1 | 9 | 8 | 7 | 6 | 3 | 2 | 5 | 4 |
| **C119** | 10 | 11 | 1 | 9 | 6 | 8 | 7 | 4 | 3 | 5 | 2 |
| **C120** | 11 | 10 | 1 | 9 | 7 | 8 | 6 | 3 | 4 | 5 | 2 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **C121** | 1 | 11 | 10 | 9 | 6 | 8 | 7 | 4 | 2 | 5 | 3 |
| **C122** | 11 | 10 | 8 | 7 | 9 | 2 | 6 | 4 | 3 | 1 | 5 |
| **C123** | 10 | 11 | 1 | 9 | 6 | 8 | 7 | 4 | 3 | 5 | 2 |
| **C124** | 1 | 11 | 10 | 9 | 6 | 8 | 7 | 4 | 3 | 5 | 2 |
| **C125** | 11 | 10 | 6 | 8 | 9 | 7 | 1 | 4 | 3 | 2 | 5 |
| **C126** | 1 | 11 | 10 | 9 | 6 | 8 | 5 | 4 | 2 | 7 | 3 |
| **C127** | 10 | 11 | 1 | 9 | 6 | 5 | 7 | 4 | 2 | 8 | 3 |
| **C128** | 1 | 11 | 10 | 9 | 6 | 8 | 5 | 4 | 7 | 2 | 3 |
| **C129** | 1 | 11 | 10 | 9 | 7 | 8 | 6 | 4 | 3 | 2 | 5 |
| **C130** | 11 | 10 | 1 | 9 | 8 | 7 | 6 | 5 | 3 | 2 | 4 |
| **C131** | 11 | 10 | 1 | 9 | 8 | 7 | 6 | 5 | 3 | 2 | 4 |
| **C132** | 11 | 10 | 1 | 9 | 8 | 7 | 6 | 5 | 3 | 4 | 2 |
| **C133** | 11 | 10 | 6 | 9 | 8 | 7 | 1 | 4 | 5 | 2 | 3 |
| **C134** | 11 | 1 | 10 | 9 | 8 | 7 | 6 | 4 | 3 | 5 | 2 |
| **C135** | 1 | 11 | 10 | 9 | 6 | 8 | 7 | 4 | 3 | 5 | 2 |
| **C136** | 11 | 10 | 1 | 9 | 8 | 7 | 6 | 3 | 2 | 5 | 4 |
| **C137** | 11 | 10 | 1 | 9 | 8 | 7 | 6 | 5 | 2 | 4 | 3 |
| **C138** | 11 | 10 | 1 | 9 | 8 | 7 | 6 | 2 | 3 | 5 | 4 |
| **C139** | 11 | 10 | 1 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 |
| **C140** | 11 | 10 | 1 | 9 | 8 | 7 | 6 | 2 | 5 | 3 | 4 |
| **C141** | 11 | 10 | 8 | 9 | 1 | 7 | 6 | 5 | 4 | 3 | 2 |
| **C142** | 1 | 11 | 10 | 9 | 7 | 8 | 6 | 4 | 3 | 2 | 5 |
| **C143** | 11 | 10 | 1 | 9 | 8 | 7 | 6 | 5 | 2 | 3 | 4 |
| **C144** | 11 | 10 | 1 | 9 | 8 | 7 | 6 | 5 | 3 | 2 | 4 |
| **C145** | 1 | 11 | 10 | 9 | 6 | 8 | 7 | 4 | 5 | 2 | 3 |

| | Mushroom Facility (MF) sequence | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **S1** | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 9 | 2 | 10 | 3 | 5 | 4 | 1 | 11 | 8 | 6 | 7 |
| **S2** | 1 | 2 | 4 | 3 | 7 | 6 | 5 | 11 | 10 | 9 | 8 | 14 | 18 | 13 | 15 | 12 | 16 | 17 |
| **S3** | 3 | 1 | 2 | 4 | 7 | 6 | 5 | 11 | 10 | 8 | 9 | 14 | 16 | 13 | 12 | 15 | 17 | 18 |
| **S4** | 3 | 1 | 2 | 4 | 7 | 6 | 5 | 14 | 11 | 9 | 8 | 10 | 13 | 12 | 15 | 16 | 18 | 17 |
| **S5** | 3 | 1 | 2 | 4 | 14 | 13 | 7 | 15 | 6 | 5 | 10 | 12 | 8 | 11 | 9 | 18 | 16 | 17 |
| **S6** | 4 | 1 | 7 | 3 | 6 | 2 | 5 | 10 | 11 | 9 | 8 | 14 | 18 | 13 | 16 | 12 | 15 | 17 |
| **S7** | 11 | 10 | 12 | 4 | 2 | 3 | 1 | 6 | 9 | 8 | 5 | 7 | 18 | 16 | 17 | 14 | 13 | 15 |
| **S8** | 17 | 11 | 18 | 9 | 7 | 6 | 8 | 3 | 4 | 1 | 2 | 5 | 12 | 16 | 14 | 13 | 10 | 15 |
| **S9** | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 1 | 4 | 2 | 3 | 5 | 11 | 10 | 6 | 9 | 7 | 8 |
| **S10** | 18 | 17 | 16 | 15 | 14 | 13 | 10 | 12 | 11 | 4 | 8 | 3 | 1 | 7 | 9 | 6 | 2 | 5 |
| **S11** | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 9 | 4 | 10 | 6 | 7 | 5 | 8 | 2 | 3 | 1 |

| | Energy Facility (EF) sequence | | | | | | |
|---|---|---|---|---|---|---|---|
| **S1** | 6 | 3 | 1 | 5 | 4 | 2 | 7 |
| **S2** | 2 | 1 | 5 | 6 | 4 | 3 | 7 |
| **S3** | 5 | 1 | 2 | 7 | 4 | 3 | 6 |
| **S4** | 5 | 1 | 2 | 6 | 4 | 3 | 7 |
| **S5** | 5 | 1 | 3 | 6 | 4 | 2 | 7 |
| **S6** | 3 | 1 | 2 | 6 | 5 | 4 | 7 |
| **S7** | 1 | 7 | 2 | 4 | 6 | 5 | 3 |
| **S8** | 7 | 4 | 6 | 1 | 2 | 3 | 5 |
| **S9** | 6 | 3 | 1 | 5 | 4 | 2 | 7 |
| **S10** | 6 | 3 | 2 | 5 | 4 | 1 | 7 |
| **S11** | 6 | 3 | 2 | 5 | 1 | 4 | 7 |