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Reverse logistics network for waste in ecotourism area based on quad tree classification

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Abstract. With the rapid development of economy, people's awareness of environmental protection has also been improved, and the eco-tourism area has been put forward to protect natural resources. Local residents and tourists produce waste, which affects the local environment and has a major impact on the disposal of these wastes. Therefore, the solid wastes which are difficult to collect were selected in this paper; based on the idea of quad tree classification, the reverse logistics network of ecotourism waste area was designed, and relevant examples were also used to verify it; and then the appropriate address was selected to build the waste reverse logistics network. The results show that the network can locate correctly.

Key words. Environmental protection, ecotourism, quadtree, reverse logistics.

1. Introduction

With the development of the world economy, people's awareness of environmental protection is also increasing [1]. Eco tourism zone, based on natural resources, is a sustainable development that can utilize the landscape advantages of scenic spots to pursue the ecological environment, the basic purpose of which is to protect the ecological environment and realize the harmonious and balanced development between man and nature [2]. This kind of tourism means that all the pollution caused by tourism activities is limited within the scope of self-purification of natural ecology and sustainable development [3]. In order to maintain sustainable development, the pollution is controlled within a certain range according to the possible self-purification capacity of various pollutants and the environment [4]. Among them, the solid waste produced by travelers is one of the main pollutants, and the collection and disposal of solid waste in ecotourism area is one of the important means to control pollution [5]. However, the collection and management of solid waste are the most difficult and complex [6]. In the collection, transportation, treat-

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ment, and regeneration of solid waste management, about 60–70 % of the cost is spent on the collection, because the total cost of governance is large. If there is a slight improvement in collection, the total cost can be saved [7]. Therefore, in the design and research of waste reverse logistics network based on the idea of quad tree classification, the emphasis was on the collection of solid waste in this paper.

2. State of the art

With the gradual increase of environmental awareness, domestic and foreign scholars have conducted a multi-party research on reverse logistics network design. For example, in 1989, some scholars proposed a multi-objective mixed integer programming model to select the mode of transportation of recycled goods [8]. In 1993, a multi-objective mixed integer programming model and a heuristic algorithm were proposed to solve the problem of location and allocation of municipal solid waste facility services [9]. In 1998, some scholars developed a network structure system for regenerating sand from building waste, and established a three-level location model with capacity constraints [10]. In 2000, some scholars used the establishment of multiple target models to study the waste management system in Taiwan. In 2003, some scholars proposed a common model for the recovery and reuse of waste items for a two-tier site model with only one type of facility [11]. The waste was collected from the user's area and was sent to the recycling center for processing as reusable material before entering the market. According to the quantity of recycled materials, compared with the market demand, the model larger than market demand and the model smaller than the market demand were put forward, and heuristic algorithm was designed. In 2007, some scholars studied the problem of collecting discarded products from consumers and setting up recycling centers, and proposed a tabu search algorithm to solve them [12].

3. Methodology

Among the methods of operation of various waste recycling logistics systems, the more advanced method is to use the transfer station to separate waste collection and transportation, and to collect waste with a collection vehicle with a compression device and transport the waste to a treatment plant using a large capacity vehicle [13]. The most important thing in this model is the selection of the relay station and the planning of the vehicle path [14]. Most of the research at this stage is a straight line, and some scholars have studied the collection of waste on the route, taking into account the fact that the amount of waste collection is constant.

If the transfer station is built within the scope of the study, the points produced are divided, and the number of waste generated by each point is also known, after investigation, the optional site suitable for setting up transit stations can be selected [15]. At present, the following problems should be solved: (1) the number and location of the transfer station should be established; (2) the driving route of the vehicle should be collected, that is, site selection-path selection problem. Site selection -

path selection problem, it is generally considered that there are some known demand points and candidate facilities in the plane of the study, the location of the facility is selected in the candidate facility, and the route to the demand point is given at the same time. According to the requirements of the objective function, the tour path is determined, and usually the objective function is the minimization of cost.

Site selection - path selection problem, the key point is to establish a mixed location - path model with good number and location of facilities. Under certain constraints, the best transportation route can be selected, so that the total cost is lowest. The total cost generally includes fixed investment in facilities, operating costs, vehicle capacity and quantity limits. Site selection - path selection problem is generally divided into two algorithms: precision algorithm and heuristic algorithm.

The production of solid waste in the tourist area is caused by: (1) aboriginal residents, fixed production; (2) foreign tourists, uncertainty production. In this paper, it was assumed that the production of solid waste in tourist attractions was divided into three periods: season, off-season and flat season, and the method and route of garbage collection were considered.

In this paper, the disposal plant was not in the tourist area. In the selection of solid waste collection-routing problem, only the location routing problem from point of arrival to transfer station was considered. All vehicles started from the parking lot, passed through the transit station and returned to the parking lot, and all the vehicles were the same. Each vehicle was responsible for collecting only one route. The main objective was to minimize the cost of fixed investment and operating costs of the whole system.

The size of the transfer station was determined according to the amount of garbage transfer. The amount of litter transport should be based on the actual data of the daily output of the garbage in the service area of the tourism service area. Therefore, the transfer route should be changed according to the situation of the high season and off-season peace season.

The model must first meet the following conditions:

$$x_j = \begin{cases} 1, & \text{If you build a transfer station at } J \\ 0 & \text{otherwise} \end{cases}$$

$$y_{jk} = \begin{cases} 1, & \text{The vehicle } K \text{ passes through the transfer station } j \\ 0 & \text{otherwise} \end{cases}$$

$$z_{jk} = \begin{cases} 1, & \text{The vehicle } K \text{ goes straight to the node } j \text{ from a road node } i \\ 0 & \text{otherwise} \end{cases}$$

The best site selection model of solid waste collection in the tourist area is:

$$\text{Min} \sum_{j \in J} f_j x_j + \sum_{k \in K} \left[\frac{C}{2} \left(\sum_{j \in N} \sum_{i \in N} Z_{ijk} d_{ij} \right) \times \sum_{j \in N} \sum_{i \in I} Z_{ijk} h_i^I \right]. \tag{1}$$

$$\sum_{k\in K}\sum_{j\in N} Z_{ijk} = 1, \qquad (i \in I)\,, \tag{2}$$

$$\sum_{i\in N} Z_{ijk} - \sum_{i\in N} Z_{jik} = 0, \qquad (j \in N, k \in K)\ , \tag{3}$$

$$\sum_{i\in S}\sum_{j\in S}\sum_{k\in K} Z_{ijk} \le |S| - 1, \qquad 2 <\ |S| \le |I|\ , \tag{4}$$

$$y_{jk} \le x_j, \qquad (j \in J, k \in K)\,, \tag{5}$$

$$\sum_{j\in J} y_{jk} = 1, \tag{6}$$

$$\sum_{i\in I} h_i^I Z_{ijk} \le Q_{\mathrm{C}}, \qquad (j \in N,\ k \in K)\,, \tag{7}$$

$$\sum_{i\in I} Z_{ijk} = y_{jk}\ , \tag{8}$$

$$z_{j0k} = y_{jk}, \qquad (j \in J,\ k \in K)\,, \tag{9}$$

$$N_1 \le \sum_{j\in J} x_j \le N_2, \tag{10}$$

$$x_j \in \{\ 0,\quad 1\ \}, \qquad (j \in J)\,, \tag{11}$$

$$y_{jk} \in \{\ 0,\quad 1\ \}, \qquad (j \in J,\ k \in K)\,, \tag{12}$$

$$z_{ijk} \in \{\ 0,\quad 1\ \}, \qquad (i, j \in J,\ k \in K)\,. \tag{13}$$

Here, the parking lot is Q, the solid waste collection point is I, the collection point of the parking lot, the solid waste collection point and the transit station is N, the candidate site of the transit station is J, and the amount of solid waste produced at point i is $i \in I, \quad I = 1, 2, 3 \quad \text{high season, shoulder season, low season}$.

The objective function (1) is the sum of the location cost of the transfer station and the transportation cost of the waste. The double sum $\sum_{j\in N}\sum_{i\in N} Z_{ijk}d_{ij}$ is the total distance on the kth road, while the double sum $\sum_{j\in N}\sum_{i\in I} Z_{ijk}h_i^I$ is the total amount of traffic on the kth road. For ease of calculation, it was assumed that the waste ran at half the total distance on the Kth circuit. Formula (2) means that each collection point only appeared on one road, and formula (3) represents the network stream conservation constraint. Formula (4) represents the standard branch elimination constraint, formula (5) means that only when the transfer station was built, the collection vehicle could pass through. Formula (6) means that a vehicle only passed through the transfer station, formula (7) indicates the limit of vehicle loading capacity and formula (8) means that the vehicle passing through the transfer station must have a line from the collection point to the transfer station. Formula (9) shows that when the vehicle passed through the transfer station, the transfer station and the parking lot being connected and formulas (8) and (9) also ensured that the collection vehicle was returned to the parking lot after unloading at the transfer station. Formula (10) represents the number of transfer stations, while formulas (11), (12) and (13) give the decision variables.

Location–path selection problem was divided into 2 steps, namely, the partition of the collecting points and the determination of the route and location.

(1) Collection point partition. The method of the quad tree was used to select the collection points that were relatively concentrated at the geographic location, and the total production of the collection points in the candidate area was equal to or close to the total capacity of the vehicle.

(2) Location and route determination. Heuristic algorithms were used to locate and determine the routing routes for each partition.

Quad tree can continuously divide the geographical space into four parts, so as to form a grid of $2^k \times 2^k$, which can better describe the relationship between point and line in the geographical space. The quad tree method has the advantages of quick and concise technology. The quad tree classification can solve the problem of location partitioning. Therefore, in this paper, the quad tree principle was used to determine the location and the candidate partition.

The idea of the quad tree is to divide the geographical area into four parts. The four regions are regarded as the first layer of the division, and then, the four branches of the first layer are divided into four equal branches until the area satisfies the set condition. Specific steps are as follows:

Firstly, the coordinate system is established, the parking area is the origin, and the relative coordinates $v_m = (a_m,\ b_m)$ are used at the point of need.

Secondly, quad tree is generated, the maximum network length of quad tree is established with the maximum absolute value of a_m and b_m. The criterion of generating quad tree is that the amount of each partition is less than the market demand. If the amount of the partition is greater than the market demand, it will be split until the amount of each partition is less than the market demand.

Thirdly, the candidate partitions are merged and formed, merged from the bottom layer, and the principle is that their upper layers belong to the same branch. The minimum distance from the last two points in the grid is merged, and the distance between the two points in the two grids cannot exceed the distance from the nearest point to the transit station and ensure that the collection of the grid after the merger does not exceed the market demand, and then followed by the merger, the lower that cannot participate in the merger can participate in the merger of the upper, the merging principle is the same. The mesh is as minimal as possible, and a grid of candidate points is removed to form a candidate partition.

Tour path and location: after the partition becomes a small TSP problem, the lingo8.0 (related interface, shown in Fig. 1) is adopted to solve the routing and distance of the partitions in the peak season to different candidate stations, and the full enumeration method is used to find the objective function (1) based on the results, so as to achieve the optimal number of transfer stations and distribution of transfer stations. During off-season and peaceful seasons, the transfer station which is determined by the peak season can be used to change the zoning and tour routes.

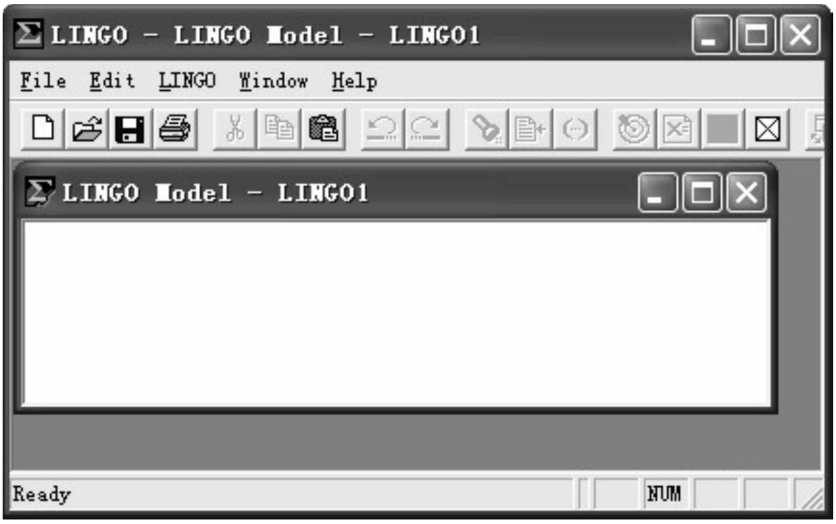

Fig. 1. Lingo8.0 operation interface

There were 5 candidate transfer stations and station costs, as shown in Table 1. The amount of waste generated at 20 different waste generation points and during the unified collection cycle is shown in Table 2. The quantity of resident location was unchanged, and the location of tourism was the point of change. The collection cycle was five days. 3 months were in the busy season. The cost per ton of waste was 11 yuan, 100 meters per kilometer. The cost and transportation cost of the transfer station were converted to the monthly cost calculation. Transportation costs were calculated according to the peak season.

Table 1. Transit station candidate point location and construction costs

Transfer station number	Abscissa system	Vertical coordinate system	Cost (million yuans)
1	11.76	14.06	55
2	4.39	3.98	57
3	13.63	8.58	47
4	7.59	6.09	50
5	16.64	3.79	51

From the above table, it can be seen that the calculation result was 1, 2 and 4, and the establishment of 3 transfer stations made the cost reach the optimum.

Table 2. Collection point coordinates and collection in different situations

Collection point number	Abscissa	Ordinate	Collecting in different cases (kg)
1	19.01	1.16	4300 4300 4300
2	4.62	7.06	3100 1200 1000
3	12.14	16.26	2900 1100 600
4	9.72	0.20	2200 2200 2200
5	17.83	2.78	1900 1900 1900
6	15.24	4.06	2900 1000 800
7	9.13	3.97	3700 3700 3700
8	7.37	9.08	4000 2000 600
9	16.43	5.44	3700 800 600
10	2.50	1.98	3000 1000 600
11	12.31	10.31	2000 2000 2000
12	15.84	8.90	2100 2100 2100
13	14.76	18.63	2600 900 400
14	3.53	9.32	2700 1000 300
15	3.53	9.32	2700 1000 300
16	8.11	8.37	3200 3200 3200
17	18.71	16.92	3400 800 400
18	18.34	10.50	3400 3400 3400
19	6.21	4.05	2900 2900 2900
20	17.87	13.44	1200 1200 1200

4. Result analysis and discussion

On the basis of the above, the amount of solid waste produced in the tourist area was changed into the reverse logistics network of solid waste recycling in ecotourism area. The establishment of reverse logistics network was based on the relevant policies and regulations of our country. According to the actual situation of our country, the teaching model of waste network design was established, which referred to the total capacity limit of the transfer station, and the waste was undergone the process from the point of production to the transfer station and then to the processing plant. If the points are divided, and the number of wastes generated by each generating point is identified, firstly, it is necessary to find out the candidate sites which are suitable for setting up processing stations, and then deal with the location of stations so as to minimize the negative impacts on the residents. And then under the condition of satisfying the total capacity limit, the freight of the transfer station should be the lowest.

The site selection is the first step in the reverse network engineering of solid waste. Its rationality affects the project cost, the operation stability and the secondary pollution control, which mainly follows the following principles: 1. the principle of safety in the view of pollution prevention; 2. the economic and reasonable principle considered from the economic point of view. Safety principle is the basic principle of processing station location. The economic principle requires that the best economic results can be achieved by using reasonable technical and economic schemes and minimizing investment, so as to achieve the goal of environmental protection. It should meet the following requirements:

(1) The site should meet the overall planning of the local construction.

(2) There are appropriate geological conditions.

(3) There are appropriate natural conditions.

(4) The impact on the environment is small.

(5) The economic costs are as low as possible, but achieve the best effect.

(6) The site selection should be in line with national policies, laws and regulations, as well as the consent of the majority of residents.

There are many solid waste generation points in the ecotourism area, including local residents' residences and various attractions. These points will be set near the transfer station, the production of solid waste will be placed near the transfer station, while establishing a processing station, its main function is to transfer the solid waste from the transfer station to classify and compress the waste. The processing station may affect the surrounding residents and tourists in the scenic area, resulting in discomfort. As a result, residents and tourists will want to stay away from them. In the site selection, both the construction cost and the wishes of the residents and tourists should be considered. Under the premise of meeting the demand, in order to determine the number and location of establish transit station, in this paper, it assumed that the AHP method was used to select candidate treatment station, and the processing station location was determined, so as to maximize the minimum distance between processing stations to residential areas and scenic spots, and make the construction site cost, operation cost and transportation cost lowest.

The traveling season was divided into the peak season, the low season and the peaceful season. In different circumstances, the number of tourists changed, so that the amount of solid waste varied. The scale of the transfer station should be determined based on the amount of refuse transfer, and the amount of refuse transfer should be determined according to the actual quantity of daily average production of garbage in the service area. Thus, the number of transfer stations was established on the basis of the peak season, while in the off-season or flat season, some completed transit stations may be closed.

The model contained the following assumptions:

(1) Waste can only be transported directly to the transfer station, transported by the transfer station to the processing station, but cannot be sent directly to the processing station.

(2) The network discrete location defined the alternative relay stations and pro-

cessing stations.

(3) The distance and waste transportation costs were simply linear.

(4) The processing station and a number of transit stations were established in the study area.

(5) If the peak season, off-season and peace season each had 3, 3 and 6 months, then $a = \{\ 3 \quad 3 \quad 6\ \}$, and at the same time, the following conditions were met:

$$x_j = \begin{cases} 1, & \text{If you build a transfer station at } J \\ 0 & \text{otherwise,} \end{cases}$$

$$y_{jk} = \begin{cases} 1, & \text{If you build a transfer station at } k \\ 0 & \text{otherwise,} \end{cases}$$

$$z_{ij} = \begin{cases} 1, & I\text{th point of waste to the } J\text{th point transfer station} \\ 0 & \text{otherwise.} \end{cases}$$

A model where the amount of solid waste is constant was:

$$\min \sum_j f_j x_j + \sum_i \sum_j a_l p_j x_j + \\ + \sum_k G_k y_k + C \left(\sum_i \sum_j \sum_k h_i^l z_{ij} y_k d_{jk} + \sum_l \sum_j h_i^l z_{ij} d_{ij} \right) , \tag{14}$$

$$\min p \,, \tag{15}$$

$$\sum_j z_{ij} = 1 \qquad \forall i \in I \,, \tag{16}$$

$$z_{ij} < x_j \qquad \forall i \in I, \ \ \forall j \in J \,, \tag{17}$$

$$d_{ik} y_k \geq P \qquad \forall i \in I, \ \ k \in K \,, \tag{18}$$

$$\sum_i h_i^l z_{ij} \leq Q_j \,, \tag{19}$$

$$\sum_k y_k = 1 \,, \tag{20}$$

$$x_j, y_k, z_{ij} \in \{0, 1\} \qquad \forall i \in I, \ j \in J, k \in K \,. \tag{21}$$

The objective function (14) represented the minimization of construction cost, operation cost and transportation cost. The objective function (15) represented the maximum distance from the point at which the waste was generated to the nearest processing station, and was defined in the constraint (18). Condition (16) ensured that each point was only shipped to a transfer station and (17) ensured that only in the construction of jth transfer station, waste in i can be shipped to$j$. The condition (19) represents the total capacity limit of the transfer station, (20) only built a processing station and (21) indicates that the decision variable was 0 or 1 for the variable.

There were four processing stations, five transit station candidate sites and construction costs, as shown in Table 3. Fig. 2 shows the amount of waste generated at 20 different waste generation points during a collection cycle. SPSS20.0 software (the operation interface shown in Fig. 3) was used for analysis and finishing, and the results are shown in Table 4, of which, 5 days was a collection cycle. The freight cost per ton was 100 yuans per kilometer, representing 1 kilometer per unit distance. A reasonable distance was 4.1 kilometers, $\delta_p = 0.5$. The cost per month included reasonable costs, station and transfer costs of processing station and transfer station, so the reasonable cost was converted into reasonable cost per month, $T = 65\delta_T = 6.5$.

Table 3. Processing station candidate point location and station cost

Processing station number	Abscissa system	Vertical coordinate system	Cost (million yuans)
1	8.12	14.06	200
2	12.09	5.89	190
3	5.93	13.88	215
4	15.03	13.88	215

When the maximum satisfaction degree of the objective function was 85 %, the processing station was set at (8.12, 14.05) with number of 1, and the transfer station was established at (11.76, 14.06), (7.59, 6.09) and (16.63, 3.79).

5. Conclusion

The main purpose of the eco-tourism area is to use the advantages of the scenic area to minimize the damage to the environment to carry out tourism. In recent years, with the economic improvement, people's awareness of environmental protection has gradually increased. Although ecotourism has reduced pollution to the environment as much as possible, local residents and tourists still produce waste. How to deal with waste has an important impact on environmental protection, of which, the collection and management of solid waste are the most complex. Thus, the solid waste was selected as the object of study, the present situation of waste reverse logistics network was briefly introduced. Based on the idea of quad tree classification, the optimal site selection model of solid waste collection in tourism area was established and a model for the constant production of solid waste was established. And then the research on the reverse logistics network design for waste

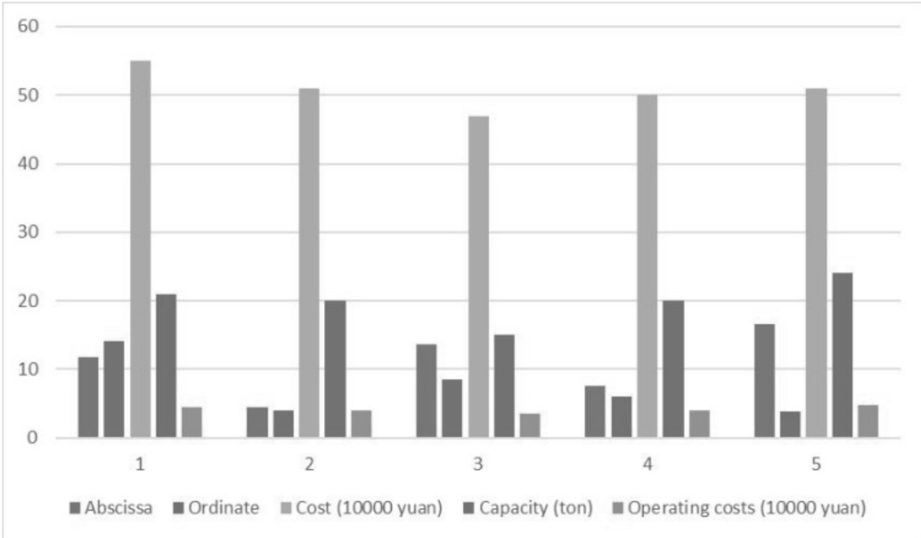

Fig. 2. Location of transit point, station cost and monthly operating expenses

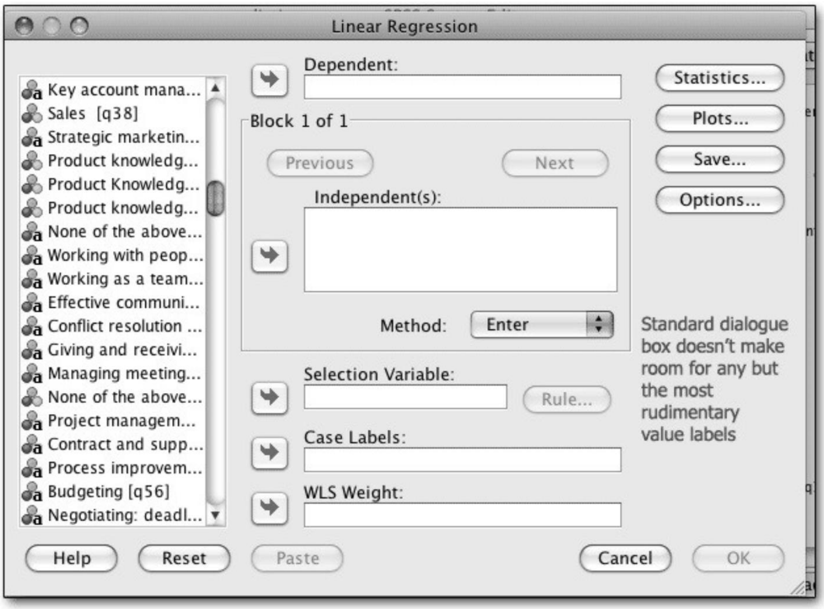

Fig. 3. SPSS 20.0 operation interface

in ecotourism area based on quad tree classification was carried out and verified by the relevant examples. The results show that the network can be located correctly.

Table 4. Collection point coordinates and collection in different cases

Collection point number	Abscissa	Ordinate	H_i^l (kg), ($i = 1, 2, 3$	δ_i (kg)
1	19.01	1.16	4300 4300 4300	500
2	4.62	7.06	3100 1200 1000	200
3	12.14	16.26	2900 1100 600	200
4	9.72	0.20	2200 2200 2200	300
5	17.83	2.78	1900 1900 1900	300
6	15.24	4.06	2900 1000 800	200
7	9.13	3.97	3700 3700 3700	400
8	7.37	9.08	4000 2000 600	300
9	16.43	5.44	3700 800 600	200
10	2.50	1.98	3000 1000 600	200
11	12.31	10.31	2000 2000 2000	300
12	15.84	8.90	2100 2100 2100	200
13	14.76	18.63	2600 900 400	300
14	3.53	9.32	2700 1000 300	200
15	3.53	9.32	2700 1000 300	200
16	8.11	8.37	3200 3200 3200	400
17	18.71	16.92	3400 800 400	200
18	18.34	10.50	3400 3400 3400	400
19	6.21	4.05	2900 2900 2900	300
20	17.87	13.44	1200 1200 1200	200

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