Agro-Prosumer Community Groups

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Background. The involvement of prosumers in the form of agricultural community groups has been acknowledged, and interest in it is increasing due to local food demand and quality of food. How to create a prosumer group? The definition of agro-prosumers and analysis of their behaviour, engaging new members to the existing groups, managing members and their goals are important factors to consider. Hence, to overcome this barrier and to improve the participation of prosumers, in this paper three key frameworks are presented to develop an Agro-Prosumer Community Group (APCGs) platform.

Methods A conceptual process that consist of strict multiple stages i.e. requirement analysis, design logic, theoretical fundamentals, implementation of prototype and verification, is used to build the frameworks for APCG. Different methods and approaches are used to design and develop framework's prototype. For instance, clustering algorithms are used to define and group agro-prosumer concept, an approach is developed that evaluates real-time production behaviour of new prosumers while engaging them to APCG. Finally, the goal-ranking techniques i.e. MCGP are used to build a goal management framework that effectively reaches a compromise between diverse goals of APCGs.

Results Results for each framework is shown while verifying the prototype using prosumers data.

Conclusion An Agro-Prosumer Community Group addresses three key issues relevant to the development of an agro-prosumer community-based approach to manage the prosumers in local food- and carbon-sharing networks. The key contributions are 1) APCG concept, 2) Prosumer engagement framework, and 3) Goal management framework. Thus APCG platform provides a seamless structure for carbon and produce sharing network.

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13 Abstract

14 **Background.**

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16 acknowledged, and interest in it is increasing due to local food demand and quality of food. How
17 to create a prosumer group? The definition of agro-prosumers and analysis of their behavior,
18 engaging new members to the existing groups, managing members and their goals are important
19 factors to consider. Hence, to overcome this barrier and to improve the participation of prosumers,
20 in this paper three key frameworks are presented to develop an Agro-Prosumer Community Group
21 (APCGs) platform.

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24 theoretical fundamentals, implementation of prototype and verification, is used to build the
25 frameworks for APCG. Different methods and approaches are used to design and develop
26 framework's prototype. For instance, clustering algorithms are used to define and group agro-
27 prosumer concept, an approach is developed that evaluates real-time production behavior of new
28 prosumers while engaging them to APCG. Finally, the goal-ranking techniques i.e. MCGP are
29 used to build a goal management framework that effectively reaches a compromise between
30 diverse goals of APCGs.

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35 an agro-prosumer community-based approach to manage the prosumers in local food- and carbon-
36 sharing networks. The key contributions are 1) APCG concept, 2) Prosumer engagement
37 framework, and 3) Goal management framework. Thus APCG platform provides a seamless
38 structure for carbon and produce sharing network.

39 Introduction

40 Prosuming, individually or as a group, is seen as a political act which is feasible, reduces
41 unfavorable environmental changes and affects the economy by reducing centralized long-chain
42 value in the supply chain [1]. Thus, prosuming in urban agriculture can be perceived as a
43 sustainable step for the agriculture industry.

44 With the growing interest in the supply of quality food, the urban prosumer can be seen as a leader
45 in providing high quality, trustworthy produce. Prosumers' crop yields are not only considered
46 high quality as generally they are home grown, but are also chemical free, grown in better soil (i.e.,
47 composting) or grown organically. Additionally, prosumer crops are more trustworthy and better
48 quality than commercial produce as they are usually home grown from seeds or seedlings, as is
49 the practice of the urban prosumer. Hence, an agro-prosumer has strong prospects of obtaining
50 better value and exposure in the market by forming or joining a prosumer community group.

51 An agro-prosumer community group (APCG) can be described as a community group network
52 formed by "using different agro-prosumers profile, personal motivations and unique
53 characteristics". Forming an agro-prosumer community group has a number of benefits such as it
54 can improve economic value and offer rich socio-psychological experiences [1] to the agro-
55 prosumers by creating social relationships and self-pride, imparting new skills to members,
56 generating knowledge, and contributing to community activities. In addition to high quality
57 produce, agro-prosumers can generate carbon tokens depending upon the consumption of the total
58 amount of carbon content consumed during the vegetation process, and trade it with industries.
59 APCGs can also reduce the long supply chain work, thus improving transparency, security and
60 sustainability.

61 To build an APCG network, first step is to define APCG and identify prerequisites. To achieve
62 this, a framework is designed where agro-prosumers' profiles are assessed and analyzed to form
63 different groups and derive each group's unique pre-requirements. These unique requirements will
64 become the prerequisites of each group and will be utilized to classify prosumers into appropriate
65 group. The framework utilizes agro-prosumers' production history when deciding the pre-
66 condition criteria for each APCG.

67 Furthermore, engaging new agro-prosumers is critical to make APCGs a sustainable network. Thus
68 as a next step an APCG require a recruitment framework to add new agro-prosumer in the network.
69 For new recruitments, it is important to evaluate the new agro-prosumers' real-time production
70 profiles before offering them membership of their desired APCG. Thus, rather than relying on
71 historic production behavior, it is important to use real-time production profiles, which will give a
72 better understanding of the prosumer's commitment to supporting the APCG. Hence, we propose
73 a framework for recruiting new agro-prosumers for an APCG. The recruitment is based on an
74 evaluation of their real-time commitment conducted over a defined period.

75 After initiating the community-based, produce-sharing network, one of the key requirements is to
76 make APCGs goal-oriented. This can be done by determining the overall community objectives of
77 the production-sharing network and, subsequently, managing diverse multiple goals of the various
78 APCG groups.

79 Goal management can be challenging in a community-based network due to diverse conflicting
80 issues such as demand constraints and cost constraints. Several situations can occur where one
81 objective is achieved while leaving another. For instance, in order to improve carbon sequestration
82 in soil by APCGs, organic/ecological farming ways must be practiced; however, organic farming
83 methods yield less, which in turn affects the collective produce of the APCGs and subsequent
84 income. Therefore, it is a requirement that a compromise be applied to the multiple goals with
85 respect to the given constraints. Based on the above discussed factors an effective framework for
86 the management of goals is essential. Thus another key framework is developed and termed as
87 goal management framework. The paper presents a seamless structure to develop an agro-
88 prosumer community group network by proposing and verifying three sub frameworks i.e. APCG
89 definition and prerequisites, APCG new prosumer recruitment and Goal management for APCGs.

Materials & Methods

Framework 1 APCG definition and prerequisites

92 The key input for the APCG's definition and pre-conditions-determining framework is agro-
93 prosumer's produce profile. Agro-prosumers' produce profiles are selected based on the suburb or
94 postcode and types of crops grown in their garden, along with the quantity during different seasons,
95 particularly winters and summers. Outputs derived from this framework will become the
96 prerequisites for different APCGs. The pre-condition requirement for each member will be treated
97 as a commitment to meet their group's prerequisites.
98 The framework is divided into two parts as shown in Figure 1.Phase 1: clustering prosumer profiles
99 and outlier detection, and Phase 2: optimizing prosumer clusters to define group's pre-conditions.
100 Agro-prosumers' seasonal summer and winter data has been collected as an input for the first part
101 of the framework. Kmeans algorithm has been worked out, however the objective here is to find
102 out prosumers based on similar production behavior. Therefore, an hierarchical clustering
103 algorithm shown in Figure 2 is used to create clusters based on the homogeneity of prosumers'
104 profiles, and to detect outliers. Homogeneity of prosumers with similar produce profiles will help
105 in earning fair amount of incentives for all and will also support easy incentive distribution[2].
106 Clusters are optimized and unique attributes are identified in the second part of the solution. The
107 non-overlapping agro-prosumer clusters from the first part are optimized to achieve a feasible
108 number of APCGs, and unique attributes are identified for each group and used as pre-requisites
109 of APCGs.

Phase 1 Prosumer Clustering

111 The first phase includes clustering of the prosumers' profiles and detecting any outliers using a
112 hierarchical clustering method. Prosumers' seasonal profiles for two seasons (summer and winter)
113 are taken as an input for this phase. There are three steps in this phase: creation of regional groups,
114 building clusters, and outlier detection.

Step I Creating regional groups

116 In this phase, agro-prosumer's postcode is taken as an input. The prosumers are partitioned into
117 groups based on their postcodes within a certain region. This will mean that the delivery of
118 prosumer produce can be done without the need for long-distance transportation. The output of

119   this step will provide GL-clusters (geographical location based- clusters) based on postcodes and
120   the neighborhood zone.
121   **Step II Outlier detection**
122   In order to deal with outliers, a threshold is set: after calculating the distance between existing
123   clusters, if the shortest distance is not further than the threshold, we assign the dataset to its closest
124   cluster. If the shortest distance exceeds the threshold, this means that the cluster could belong to a
125   minor group. The objects in the minor group are those that did not belong to any major groups.
126   Objects in minor groups are data points, not outliers as they do not belong to any major groups.
127   Further clustering of objects in minor groups can be done for future analysis.
128   **Step III Building clusters**
129   For each GL-cluster obtained from step one and after removing outliers, the corresponding agro-
130   prosumer profiles are considered in the next step, and clusters are formed based upon prosumers'
131   production history. The hierarchical clustering method is used to decide the number of clusters.
132   Initially, each prosumer profile is placed in a unique cluster. For each pair of clusters, some value
133   of dissimilarity or distance is computed. In this case, minimum variance, i.e., Ward's criterion, is
134   used to minimize the total within-cluster variance and find the pair of clusters that leads to
135   minimum increase in total within-cluster variance after merging. In every step, the clusters with
136   the minimum variance in the current clustering are merged until the whole dataset forms a single
137   cluster. Hierarchical clustering helps in identifying groups in the dataset. Thus, the output from
138   this step will be number of prosumer clusters based on their production similarity.
139   **Phase 2 Prosumer Cluster Optimization and forming pre-requisites:**
140   This phase involves the optimization of prosumer groups based on the number of prosumers in
141   each group and their production amount. Firstly the clusters are optimized and pre-requisites for
142   each cluster-group is formed. The optimization steps and pre-requisites are further illustrated in
143   this section.
144   **Step I Optimization of prosumer clusters**
145   Agro-prosumer cluster-groups created by using hierarchical clustering are optimized to produce
146   sufficient number of clusters that will then represent different agro-prosumer community groups.
147   The number of clusters produced by optimization, depends on the variation of production quantity.
148   If the variation is large, too many clusters could be formed, which are not feasible to manage.
149   Thus, this stage involves optimizing the clusters into a feasible number of APCGs by merging
150   small clusters into one or splitting large clusters into smaller ones to obtain a feasible number of
151   APCGs to satisfy market requirements. In order to determine the ideal number of clusters, firstly,
152   suburb requirements are analyzed and the expectations of relevant APCGs are derived.
153   To optimize APCGs;
154   Let X be the population of suburb ABC and C is the per capita consumption of lemons. Assume
155   that the APCG framework targets a minimum 1% of lemon market for a suburb ABC. Then the
156   requirement ($R_{expected}$) of lemons for suburb ABC using APCGs can be calculated with
157    $R_{expected} = X*C*0.01$

158 Let L be the number of clusters formed using the clustering method, and R_L represents every
159 APCG's goal.

160 $R_L = R_{expected}/L$

161 After determining the suburb's requirements, next step optimizes the clusters by evaluating
162 number of agro-prosumers present in each APCG (as shown in Figure 3). Let say P_l and P_h
163 respectively be the lowest and highest number of prosumers expected in each group. Let R_L be the
164 minimum amount of production expected from each APCG. Prosumers count (P_{num}) and the
165 production quantity ($R_{obtained}$) from a specific prosumer cluster is shown in equations 1 and 2.

166 $P_l < P_{num} < P_h$ 1
167 $R_{obtained} > R_L$ 2

168 If the production is less than the expected amount ($R_{obtained} < R_L$), or the number of prosumers is
169 lower than the ideal number of prosumers ($P_l > P_{num}$), that agro-prosumer cluster is merged with the
170 closest prosumer cluster, and the same process continues until the prosumer cluster can meet the
171 total production requirement ($R_{obtained} > R_L$) and the number of prosumers ($P_l < P_{num} < P_h$) defined for
172 the APCG.

173 Now, if too many prosumers form an agro-prosumer clusters, the clusters are further break down
174 into small size clusters consisting of an most favourable number of prosumers and meeting the
175 production goals i.e. $R_{obtained} > R_L$ and $P_l < P_{num} < P_h$.

176 The final output of optimization will result in the optimised prosumer clusters, which are then
177 represented as APCGs. Now these APCGs are analysed to identify the unique production
178 characteristics or pattern of each group which will be denoted as the pre-requisite of the APCGs.

179 **Pre-requisite formation**

180 Introduction to APCGs includes formation of unique entry requirements for each group. The two
181 key input, as discussed in the previous sections, to determine the prosumers' adherence are the
182 "lower threshold" (*Lt*) and the "upper threshold" (*Ut*). The defined inputs used as pre-requisites of
183 each APCGs will be:

184   • Lower threshold: L_t
185   • Upper threshold: U_t

186 **Framework 2: Agro-Prosumers Recruitment Framework**

187 A new recruitment framework is designed to evaluate real time behavior of new agro-prosumers
188 and allocate them in specific APCG groups. The reason for designing this approach is to encourage
189 participation of non-farmers and new gardeners, which not only help them to estimate production
190 details, outline incentive benefits etc., but will also ease off the management of APCG in the long
191 run. Additionally this framework requirement is new and won't be justified to use CSA methods
192 which basically works on partnership basis and useful for a large piece of land[3-5]. An overview
193 of the framework is shown in Figure 4.

194 New agro-prosumers who are interested in joining the APCGs, and their real-time behavior
195 profiles, are collected as input for this framework. We term these agro-prosumers "prospect agro-
196 prosumers" who are assumed to be new to the community sharing network; thus, because there are
197 no previous production profiles, real-time production needs to be determined. The final outcome

198   of this framework is the recruitment of prospect agro-prosumer to suitable APCGs. This stage is
199   further divided into four components, which are explained below.
200   The framework has four components
201   1.   An approach to evaluate agro-prosumers' production performance;
202   2.   Agro-prosumers' transaction assessment during the evaluation period
203   3.   An approach to analyse agro-prosumers' stability; and
204   4.   Agro-prosumers recruitment to a specific APCG after the evaluation period.
205   The varying nature of agro-prosumers' production behaviour is evaluated using the above
206   approaches, and allocates them to a temporary "variable APCG". Later on, the prosumers' overall
207   behaviour is stored and evaluated prior to recruitment to a specific APCG, i.e., to one of the final
208   APCGs. The requirements for the proposed solution are covered via four components (listed
209   above) discussed in detail below.

210   **Approach to evaluate prosumers' production performance**
211   Finding an approach to estimate agro-prosumers' performance is the first component of the
212   evaluation technique, which helps in understanding the evaluation period activities and evaluation
213   inputs.

214   **Agro-prosumer evaluation measures**
215   As discussed previously, the "evaluation period" is an established period of consecutive seasons
216   during which the production behavior of new agro-prosumers who are interested in joining an
217   APCG, is evaluated. The evaluation period is divided into two seasons per year in Australia:
218   winter (i.e., March-August) and summer (i.e., September- February). These winter and summer
219   seasons show non-overlapping, mutually exclusive time periods and are assigned with a production
220   transaction between agro-prosumer and the APCG module using production value.
221   Agro-prosumers' production data is generated using Australian national average. Production data
222   such as family size, farming methods (organic, inorganic), lemon variety (3 major lemon variety
223   has been used) and number of trees (1-10 has been randomly used) and their respective ages (age
224   of a tree is assumed from 5-100 years), are collected as input to evaluate their consumption pattern
225   and production performance for two season or annually. Agro-prosumers' surplus production is
226   considered as the final value for one season/year. Thus, prosumers' performance is estimated using
227   that final value, and is evaluated for each season. Next section explains the approach used to
228   determine the prosumers' performance for each season during the evaluation period.

229   **The proposed approach**
230   This approach requires two inputs: the input from the agro-prosumer and the input from the APCG
231   module as shown in Figure 5. Inputs from the agro-prosumer include production summary for a
232   season and the prosumer's preferred APCG. The APCG module's input comprises the pre-
233   requisites of the available APCGs.
234   A probabilistic approach is used here to evaluate agro-prosumers' production performance based
235   on the pre-condition criteria of their preferred APCGs.
236   Results of this approach are the "performance indices" and variable APCG of the agro-prosumer
237   for each season. Performance indices are used to anticipate the level of success and/or failure of

238 an agro-prosumer in meeting the pre-condition criteria of his/her preferred APCGs. To utilize it,
239 different levels of success and failure are represented using a four-point scale as shown in Table
240 1. In fact, each performance index shows different value or success rate of performance in the
241 production behavior.
242 The performance scale ranges from 0 to 3, where 3 represents the complete success or match, and
243 the minimum success rate is 80% for meeting the pre-condition criteria. If the success rate is less
244 than 79%, it will be considered as a "failure".
245 The performance scale used here has single-integer values. It is difficult to use extreme values,
246 i.e., only high or low, to measure prosumer behavior. Hence, in order to determine and model the
247 performance of prosumers more accurately, various levels of performance should be identified
248 first. Moreover, to accurately determine prosumer performance, the various levels of performance
249 must be identified. A performance score with a value from 0 to 3 will help to indicate prosumers'
250 performance for APCGs development.

251 • Complete success: The highest point on the performance Score is 3, which indicates
252   "Complete success". This score suggests 100% success rate in interacting with the
253   prosumers' production-sharing process. This level of performance according to the PS
254   suggests that the prosumer is strongly suited to his preferred APCG and meets the desired
255   pre-condition criteria.

256 • Intermediate success: This level denotes 90-99% of success rate in interacting with
257   prosumers' production behavior. Performance Score 2 shows that it is the "medium
258   success" level. This score suggests that in meeting the prosumers' preferred APCG
259   requirements, prosumers' performance reliability is good.

260 • Entry success: Performance score 1 indicates "Entry success". This score suggests 80-89%
261   success rate while satisfying the pre-requirements of the preferred APCG's. This
262   performance index score suggests that the prosumer is slightly reliable in meeting the
263   desired pre-condition criteria of his/her preferred APCG.

264 • Failure: 0 reflects the lowest score in performance, indicating "failure". This level depicts
265   0-79% rate of success in fulfilling the pre-requirements. Thus, this level shows that the
266   prosumer's performance is not reliable enough to meet the pre-condition criteria for the
267   APCG. Hence, the prosumer with this index could be matched with other APCG rather
268   than the preferred one.

269 The mathematical expression of performance indices is given in equation 3
270 For a season (j) of the evaluation period, the rate of success of the prosumer (P_{ij}) being allocated
271 to prefer variable APCG (C_p):
272

273 $$Rate(P_{ij} \in C_p) \begin{cases} 100\%: if\ E_{ij} \geq L_p \\ \frac{E_{ij}}{L_p}: if E_{ij} < L_p \end{cases}$$ 3

274

275 Where P_{ij} is an ith agro-prosumer's performance in the jth season, C_p is the preferred APCG, E_{ij} is
276 the real time production commitment of ith agro-prosumer and L_p is the production threshold of
277 agro-prosumers preferred APCG.

Agro-prosumers' transaction assessment during the evaluation period

279 For ongoing assessment during the evaluation period, agro-prosumer is aimed to assign into his
280 chosen APCG for each season. The evaluation process is shown in Figure 6. The key steps of the
281 process are as follows: the prospect prosumer is asked to submit records of production in real time
282 for "n" seasons during the evaluation period. For each season, dynamic production amount is
283 compared with the minimum threshold (E_{th}), which is the minimum requirement of any APCG. If
284 the prosumers' production is equal or greater than the E_{th}, the prosumer is viewed to be an eligible
285 prosumer.
286 Next, if a prospect agro-prosumer receives 'eligible prosumer' status during his/her first season,
287 she/he will be promoted to the next season and then to following seasons. However, if she/he fails
288 to meet the eligible agro-prosumer requirement, in the first production season, the evaluation
289 period will be extended with more seasons.
290 However, if the new agro-prosumer is not able to match the minimum threshold (E_{th}), then the
291 prosumer's evaluation period is extended by another season and the prosumer remains under
292 evaluation until succeeded. On the completion of the evaluation period, prospect agro-prosumers'
293 stability will be analyzed using stability index, which is discussed next.
An approach developed to analyze agro-prosumer stability
295 The stability of an agro-prosumers' reliability is estimated for his/her preferred APCG, as well as
296 for those assigned throughout the evaluation period. Figure 7 shows a process to obtain prosumers'
297 stability for agro-prosumers' chosen APCG.
298 During evaluation period, for each season, agro-prosumers' performance index values are taken as
299 an input along with their temporary APCGs. Equations 4 and 5 formulates a mathematical equation
300 for the approach. SI represents the stability index which is used to determine the feasibility that
301 prosumers will remain in their preferred APCG. The output for *I* index is between 0 and 3, and a
302 higher *I* shows high chances of prosumers remaining in their preferred APCG:

303 $$I_{pi} = \frac{\sum_{j=1}^{ns} PX_{ij}}{ns} \qquad\qquad 4$$

304 Above I_{pi} is the stability index of the ith prosumer with respect to chosen APCG (C_p), PX_{ij} is an ith
305 prosumers' performance index in the jth season and ns is the number of seasons where the prosumer
306 is assigned to his/her chosen APCG. To determine most suitable APCG for an agro-prosumer, rate
307 of engagement to a specific APCG is calculated using equation 5. For example, if the agro-
308 prosumers' rate is higher for APCG1 than other APCGs, than the chosen APCG1 is seen as the
309 most favorable APCG for that prosumer's engagement.

310 $$Rate(P_i \in APCG_{Fr}) = \frac{count\ of\ (APCG_{Fr})}{ns} \qquad\qquad 5$$

311 Where P_i is the ith prosumer, $APCG_{Fr}$ is the rth temporary APCG, count of ($APCG_{Fr}$) shows the
312 total number of times the prosumer is selected to r^{th} temporary APCG during the evaluation period
313 and ns is the number of seasons.
314 The next section discusses agro-prosumer engagement to the permanent APCG based on the
315 previously-described method.
316 **Agro-prosumers engagement to the permanent APCG after the valuation period.**
317 Agro-prosumer engagement to the most suitable APCG is analyzed in this step. The overall
318 performance of prospect agro-prosumers overall performance is assessed at the end of the
319 evaluation period. Figure 8 is a flowchart showing this process. As discussed in the previous
320 section, the Stability Index, based on an agro-prosumer's performance index, is calculated
321 throughout the evaluation period. Additionally, agro-prosumers' rate of staying in temporary
322 APCGs during the entire evaluation period is assessed. Equation 6 is utilized to identify the
323 combined value of the agro-prosumer being allocated to the permanent APCG. The APCG which
324 shows the highest joined index is chosen as that prosumer's final permanent APCG.
325 $IPr\left(P_i \in APCG_{Fr}\right) = I_{pi} \times Rate(P_i \in APCG_{Fr})$ 6
326 **Framework 3: Goal Management Framework**
327 The input for the framework includes diverse goals for agro-prosumer community groups.
328 The solution framework consists of a goal management component. The outcome of the goal
329 management phase is an optimized set of overall goals for the community-based, harvest-sharing
330 network. The processes involved in goal management are shown as an overview of the framework
331 in Figure 9.
332 **Goal management**
333 The goal management stage is responsible to attain ideal goals structure out of overall goals. The
334 purpose involves solving diverse conflicting goals in the APCG to obtain best solution in terms of
335 goals priority. The feature of MCGP [6] and an approach utilised in smart grid goal management[7]
336 is referred to design best possible solution for conflicting goals. To achieve this, each and every
337 identified objective is attached with a rank based on their priority. High rank objectives are treated
338 as goals to work out first, and therefore attempts are made to find a solution which is close to the
339 pre-ranking set of goals. Goal programming minimises the deviation between the theoretical goals
340 and realistic achievements. These deviation can be both positive and negative, thus an objective
341 function is used to minimise the deviations based on the relative importance of the goals.
342 Various areas has utilised goal programming model benefits such as environment, energy, smart
343 grid, academic and health planning [2], and shows success in solving diverse conflicting goals. In
344 this framework, we adapt MCGP techniques for our framework. Figure 10 presents the algorithm
345 for the goal programming model, where the parameters and equations are explained in the
346 following section. The model has six parts:
347   (i)   APCGs goal recognition,
348   (ii)   Summary of variables,
349   (iii)   Objective classification,
350   (iv)   Objective ranking,

351   (v)   Goal equation formation, and
352   (vi)   Generating objective functions.

Part 1: APCGs goal recognition

APCGs diverse goals are identified in this phase. These objectives are explained below.

   I.   Carbon content objective (C1): The "carbon-capture objective" refers to the use of organic farming methods to maximize carbon capture, which will increase the carbon content which can be traded with external companies. More carbon capture will result in more carbon sequestration and less emission.

  II.   Food security within the network (F1): The goal is secure the vegetable/fruit demand of local members within the APCGs. Realistically, some members within an APCG may struggle producing sufficient quantity to meet their own consumption needs. Hence, food security of APCG members have been targeted.

 III.   Providing local food access to wider community (L2): With growing local food, APCGs can make locally grown vegetables available to the extended community such as external customers or supermarkets, greengrocers, and external consumers who are not registered with an APCG.

  IV.   Income and Incentive objective (I3): The "income and incentive objective" focus is to earn income and incentive from selling surplus production of APCGs to vegetable/fruit buyers and trading carbon tokens with industries.

   V.   Maintenance cost reduction objective (M4): This goal refers to reducing the cost of APCGs maintenance over time. For example, "maintenance cost" may represent the one time cost to build APCG platform and maintaining the database and transaction records etc. Cost related to collection and distribution of products/vegetation from members, to stores etc. Additionally providing benefits to the members may require a payment gateway which may incur cost.

  VI.   Stable APCG objective (S5): The increase in the number of active APCG members, that is, those who dynamically participate in the production-sharing or carbon-sharing network, is a "stability objective".

Part 2: Summary of variables

In order to use MCGP all variables and their deviations are identified. For APCG the idea is to identify variables and summarize their deviations to achieve ideal set of goals. The production amount and carbon tokens generated by each group will be counted as variables and maximizing/minimizing the value is considered as deviation.

Part 3: objective classification

The objectives are classified as definite and flexible constraints based on the previous objectives (part 1). At this point, the "definite goals" are outlined as mandatory requirement on the variables, whereas the "flexible goals" are outlined as the objectives nice to have but not necessary [8] . The classification of goals are as follows:

389   I.   Definite goals: Maximum carbon capture objective (C). For example, the APCG's base is
390   environmental sustainability. Thus, ecological methods must be used for APCG
391   production.

392   II.   Flexible goals: Goals such as local food security (F1), extended community and customer
393   demand objective (L2), income & incentive objective (I3), maintenance cost objective
394   (M4), and stability of APCG (S5). Refinement of these goals helps in achieving the ideal
395   goal set, which would benefit APCG. The variables summaries is defined as: maximum
396   C1, minimum F1, minimum L2, minimum I3, maximum M4, and minimum S5; these are
397   termed "expected values" in the goal programming model.

398   **Part 4: Objective ranking**

399   To make sure important goals met first, the priorities of the goals have been assigned. This step
400   discusses ranking out the goals by assigning a weight (or rank) to each goal. As mentioned earlier,
401   goals can be mutually exclusive; i.e. one goal may be achievable at the expense of another. This
402   makes it critically important to assign weights to the goals, so that least important goals are only
403   met after the important ones. Keeping local network food security (F1) as priority, total goal set
404   can be determined as 4!, thus in total 24 structures will be formed such as F1L2I3M4S5,
405   F1L2M4S5I3... F1S5M4I3L2.

406   Part 5: Goal equation formation

407   Mathematical relations are developed in this section for the definite and flexible goals. Equations
408   are as follows-

409   I.   Carbon capture Objective (C): Organic farming methods should be used for APCG produce
410   to increase the carbon token value.

411   II.   Food security local demand objective (GC1): Satisfying food security of APCG should be
412   focused. Thus, the purpose of this goal is to minimise the negative deviation from the
413   quantity of surplus production of each APCG.

414   Let $A_{pi} E_i$ be the extra production produced by ith APCG, k_0 and l_0 be negative and positive
415   variance respectively, and t be the number of APCGs; then the equation for food security
416   local demand objective (F1) would be:

417          $A_{pi} \times E_i \geq 0; \forall i \leq t$

418          $A_{pi} \times E_i + k_0 - l_0 = 0; \forall i \leq t$ 7

419   Considering 4 APCG groups for this framework, 4 equations will be formed ($m=4$) for
420   each group;

421          $N_{p1} \times E_1 + k_1 - l_1 = 0;$ ... $N_{p4} \times E_4 + k_4 - l_4 = 0;$

422   III.   Local community demand objective (L2): The purpose of L2 is to minimise the negative
423   variance of the total surplus production of all APCG. Assuming requirement from external
424   supermarket is R. And positive and negative variance be s and q, respectively; then the
425   equation will be formed as

426          $\sum_{i=1}^{m} E_i \times A_{pi} \geq R$

427          $\sum_{i=1}^{m} E_i \times A_{pi} + q - s = R$ 8

428   IV.   Income & Incentive objective (I3): Obtaining higher income is another requirement of the
429   framework. The minimum income expectation of the ith APCG be Ii, and positive and
430   negative variance be q1 and s1 respectively; then the equation for this objective will be
431   minimizing negative variance

432    $\sum_{i=1}^{n} I_i \times E_i \times A_{pi} \geq I$

433    $\sum_{i=1}^{n} I_i \times E_i \times A_{pi} + q1 - s1 = I$ 9

434   V.   Maintenance cost objective (M4): Let say the maintenance cost allowances be M, and the
435   positive and negative variance be q2 and s2, respectively; equation for the maintenance
436   cost objective (GC4) is obtained with Equation 5.6, where Ci is the coefficient, represents
437   the cost rate of ith APCG.

438    $\sum_{i=1}^{n} C_i \times E_i \times A_{pi} \leq M$

439    $\sum_{i=1}^{n} C_i \times E_i \times A_{pi} + q2 - s2 = M$ 10

440   VI.   Sustainability objective (GC5): Let P be the minimum number of prosumers who are
441   participating in APCG, and positive and negative variance be q3 and s3, respectively; then,
442   the formula for the sustainability objective (G5) would be:

443    $\sum_{i=1}^{n} A_{pi} \geq P$

444    $\sum_{i=1}^{n} A_{pi} + q_3 - s_3 = P$ 11

445   **Part 6 Development of objective functions**
446   Finally the objective function of each goal is formulated and, best possible solution is formed by
447   minimizing the deviations from each goal. The objective functions here are the [(k1, k2, k3, k4*),
448   q, q₁, s₂, q₃]. Partitioning algorithm* is used to solve this linear goal programming problem.
449   **Goal programming solution**
450   As discussed previously, 24 priority goal structure sets are identified along with different ranking
451   order. The partitioning algorithm is utilized as a solution here, in order to solve the linear goal
452   programming problem [7]. The solution working principle implies on the definition of priority
453   structures which implies that higher-order goals must be optimised before lower-order goals are
454   even considered. The solution procedure is shown in Figure 11 which consists of solving a series
455   of linear programming sub-problems by using the solution of the higher-priority problem solved
456   prior to the lower-priority problem. All the sub-problems assigned to a higher priority goals are
457   solved first using the partitioning algorithm. The ideal tableau for this sub-problem is then
458   examined for alternative ideal solutions. If none exists, then the present solution is ideal for the
459   original problem with respect to all the priorities.
460   The algorithm then substitutes the values of the parameters for the flexible goals of the lower
461   priorities to calculate their satisfaction levels, and the problem is solved. However, if alternative
462   ideal solutions do exist, the next set of flexible goal and their objective function terms are added
463   to the problem. This brings the algorithm to the next sub-problem in the series, and the optimisation
464   resumes. The algorithm continues in this manner until no alternative ideal exists for one of the sub-
465   problems or until all priorities have been included in the optimisation [6, 8].

466   Goal management problem provides the best solution by comparing the achievable set of goals
467   when compared to the predetermined goals. Additionally the identification of the necessary
468   alterations to parameters are explained well in order to achieve all the goals in different priority
469   structures.

Results and Discussion

471   In this section, simulation parameters are illustrated for the verification of the frameworks.

472   **1) Framework 1 APCG definition and prerequisites**
473   a) **Simulation:** As shown in Table 2, the key parameters for the verification are the prosumer
474   production dataset. This framework is proposed using one type of crop only: lemons. It is
475   challenging to obtain a dataset for lemon yields because prosumer community group data is
476   not publicly available. Therefore, prosumer production profiles are generated using minimum
477   and maximum lemon production and consumption. In the sub-section below, we discuss the
478   generation of prosumer profile data.
479   In this section, prosumer profiles are generated using the Australian standard production and
480   consumption pattern (as shown in Table 3).

481   Country/region: In order to generate prosumer profiles, production parameters are analyzed
482   particularly for the State of Victoria, Australia. For this study, prosumers residing in Victoria
483   are used only to generate a sample data set. Therefore, Victorian suburban postcodes are
484   randomly generated for prosumers. The average residential block of land is utilized to generate
485   land sizes across Victoria. For each postcode, latitude and longitude values are determined in
486   order to build prosumer community groups that are in close proximity.
487   Vegetation/fruit: Lemon trees generally produce the first crop after three years, and reach
488   maturity when they are about five years old. Hence, the age of lemon trees and the variety are
489   considered when estimating the minimum and maximum number of lemons produced during
490   harvest season, and assessing the amount of carbon absorption. For this study, we consider
491   three of the most common varieties: Eureka, Meyer and Lisbon.
492   Farming method: Organic and inorganic methods affect the production by 10-30%. Organic
493   methods that involve composting, no tilling and no chemical fertilizers can reduce the quantity
494   produced by 20-30%. Thus, this input is also considered when generating the dataset.
495   Lemon Consumption Rate: For prosumers, it is important to estimate their family consumption
496   and calculate the surplus production that can be shared with the community or market. To do
497   so, the per capita consumption of lemons is estimated and average family size is determined.
498   Finally, prosumer consumption is calculated and averaged out to obtain the lowest production
499   and highest production rates.
500   Lemon Production Rate: As a lemon tree ages, its yield increases. When it reaches maturity
501   after five years or so, it can produce an average of ~1500 lemons. The total amount produced
502   also depends on whether organic or inorganic farming methods have been used. Therefore, the
503   farming method used and the age of the lemon tree are combined to estimate the average
504   production for a season or a whole year. Finally, the estimated average production amount is

505   assessed and consumption is calculated to obtain the LYC and HYC. The LYC and HYC show
506   the maximum contribution for the season that can be expected from a prosumer.
507   After determining the production-sharing rate, we randomly generate 200 production profiles
508   (shown in Figure 12), which are then used to verify the proposed framework for APCG
509   definition and pre-condition characteristics.

510   b) **Verification process:** For this verification, R software and programming language have been
511   used. The following parameters are used for simulating the APCG definition and the
512   prerequisites framework.
513   Firstly, the agro-prosumer profiles are collected and the dataset is prepared and checked for
514   data quality. For instance, the production and consumption of agro-prosumers are analyzed
515   and if the maximum production share is less than 50 for a season, this profile is discarded. For
516   this framework, 300 prosumer profiles were obtained as a sample, of which five were discarded
517   as their HYC was less than 50.

518   Next, the dataset consisting of prosumer profiles is partitioned according to suburb or
519   municipal boundaries, and irrelevant profiles are removed. Of the 300 prosumer profiles, 87
520   prosumers belong to "G-206 clusters" and 200 prosumers belong to "G-207 clusters". The
521   remaining eight profiles are kept in a small extra cluster as outliers.
522   The resulting clusters, G-206 and G-207, are obtained after removing the outliers. These
523   clusters are further partitioned into different prosumer groups based on their production rate
524   using the hierarchical clustering method described in section 3.5. For G-206, hierarchical
525   clustering resulted in four clusters. Figure 13 illustrates the number of prosumers allocated to
526   G-206 clusters where c1, c2, c3 and c4 denote four cluster groups produced by the hierarchical
527   method. The same hierarchical clustering is done for the G-207 cluster, which resulted in eight
528   clusters: c1 to c8 (Figure 14).
529   However, as shown in Figures 13 and 14, some clusters have a very large number of prosumers;
530   for instance, there are more than 30 agro-prosumers in c3 of G-206, and nearly 60 in c1 of G-
531   207. APCGs need to have a reasonable number of members in each cluster: small clusters can
532   cause inefficiency or overheads, and large clusters can overproduce and cause storage
533   problems or damage (such as infections) to the produce. Hence, in this scenario, the
534   optimization of the clusters by splitting the large clusters is done in order to ensure an
535   appropriate number of members.
536   In addition, Figures 13 and 14 show clusters which are too small where the number of agro-
537   prosumers is less than or little more than ten. For example, cluster c2 in Figure 13 offers only
538   11 agro-prosumers and c8 in Figure 14 has only eight agro-prosumers. If the APCG fails to
539   supply an adequate amount of produce to the buyers or market, it might not enjoy good value
540   or strong relationships in the long term and may become unsustainable. Therefore, in this
541   scenario, adjacent prosumer clusters are merged in order to meet the amount of production
542   required of members. For this data set, we reduce the number of clusters, merging the neighbors
543   into one cluster. These finalized clusters constitute the APCGs.

544   We optimize the originally obtained agro-prosumer clusters into an optimal number of APCGs
545   in order to reach the maximum and minimum number of members expected in each APCG,
546   and the minimum amount of production from each APCG. For G-206, we divide the large
547   clusters into two APCGs by splitting the production quantity further down (we assume 10
548   prosumers min. and 40 prosumers max.) in each APCG, and each APCG collectively produces
549   quantity (at least---). These finalized clusters are illustrated below in Figure 15 for G-206
550   clusters. Similarly finalized clusters are produce for G-207.
551   Tables 4 and 5 illustrate the numerical distribution of prosumers into APCGs for G-206 and
552   G-207 respectively. Using the distribution, similar patterns can be used to define and
553   characterize the APCGs. Next, the pre-condition step is used to characterize the APCGs' entry
554   requirements. Table 6 combines the average production and summarizes the pre-condition
555   criteria for different APCGs during a season. The pre-condition criteria are provided to any
556   interested prosumers to give them a better understanding of the entry requirements for a
557   community-based, produce-sharing network.

558   **2) Framework 2 Agro-prosumer recruitment framework**
559   a) **Simulation:** For verification and validation of the agro-prosumer recruitment framework, the
560   solution framework is simulated using MATLAB and Excel. The setting here is a basic set-up
561   for the examination of the proposed framework. To verify the proposed algorithm, 50 agro-
562   prosumers production profiles were generated, assuming that these 50 agro-prosumers have
563   shown interest in joining APCGs. For dataset generation, production behavior along with
564   consumption patterns from framework 1 are used. Data is obtained for summer and winter
565   seasons for four APCGs that are defined and characterized for framework 1. Four seasons are
566   used for the evaluation period: two summers and two winters. Thus, a prosumer is evaluated
567   over a two-year period.
568   The simulation parameters for new agro-prosumer framework are listed in Table 7.

569   Eligible agro-prosumers are identified during the evaluation conducted after each season of the
570   evaluation period. Only those agro-prosumers who satisfy the "eligible production threshold" in
571   the first season can proceed to the next season. Also, eligible agro-prosumers choose their preferred
572   APCG. The assumption here is that registered users cannot change their selection of preferred
573   APCG until the end of the evaluation period; thus, the preferred APCG remains fixed for four
574   seasons.
575   However, the eligible agro-prosumers readiness' in meeting the preferred APCG's pre-condition
576   criteria may be irregular over the seasons during the evaluation period. To solve this issue, as we
577   mentioned that the registered agro-prosumer is required to meet the lower threshold value of the
578   preferred APCG to be able to meet the evaluation criteria. Additionally, to determine the extent to
579   which a registered agro-prosumer meets the pre-condition criteria of the chosen APCG, four
580   performance indicator groups are introduced with values: "3", "2", "1" and "0" indicating "total
581   success", "medium success", "low success" and "failure", respectively.
582   In this simulation, the prospect prosumers' capability in meeting their chosen APCG's pre-
583   condition is assessed at first. Figures 16, 17, 18 and 19 show the percentage of prosumers who are

584   allocated to different performance indices over the four seasons (or two years) for different
585   APCGs, i.e., APCG1, APCG2, APCG3 and APCG4. Result shows APCG 1 and 2 shows
586   prosumers easily satisfying the pre-requisites when compared to APCG 4 which shows variation
587   due to high entry pre-requirements.

588   **3) Framework 3 Goal management**
589   a) **Simulation:** The solution is developed using LINGO, and is discussed in the following sub-
590   section. Table 8 shows some of the parameters for the goal programming problem that are
591   obtained based on the available data; some parameters are assumed based using the Australian
592   conditions, as real data could not be accessed or found. Here, we take the four APCGs defined
593   by APCG definition and prerequisites framework. To ease the calculations, local food security
594   demand objective is chosen top priority and keep it the same for all the possible solution
595   structures. Thus reducing total possible solutions to 4! i.e. 24 structures. The different priority
596   structures are formed, where the position of the characters ("F1", "L2," "I3," "M4" and "S5"]
597   shows the priority order of the different goals. LINGO-32 is used to program the algorithm.
598   The observations and results obtained by solving the goal problem in LINGO is presented in
599   next section.
600   b) **Verification:** The solution predicts the division of the objective function according to the
601   process priority level and the sequential solution of the resulting mixed integer linear
602   programming model. The solution obtained at each priority level is used as a constraint at the
603   lower level. The general examples discussed here are intended to illustrate the model's
604   applicability to the problem of practical dimensions.
605   For instance, I3 on priority sets the objective function for I3 to 0, but increases objective
606   function for L2 to 35564.50. When L2 is set on priority M4 successfully met but I3 increases
607   to 11650. When setting L2 on priority increases the I3 to 11651 and M4 to 84446. Setting M4
608   achieve just for M4 but does not met for L2 and I3. Same applies for S5. So, putting I3 on top
609   achieves the most except for S5. Hence, making S5 the next priority will help to achieve all
610   desired goals. Putting L2, I3 and M4 objective function together on same priority help achieve
611   the best. Therefore, the negotiated priority set of goals are CF1L2I3M4S5 which is illustrated
612   in Table 9.

613 **Conclusions**

614   In order to build a seamless Agro-Prosumer Community Group structure, three key frameworks
615   have been proposed in this paper to build a sustainable network for production sharing network.
616   An APCG definition and prerequisites framework has been proposed to categorize the agro-
617   prosumer profiles into feasible APCGs, while defining the pre-condition criteria for each APCG.
618   These pre-condition criteria defined for each APCG can be utilized when recruiting new agro-
619   prosumers, i.e., the new agro-prosumers may be required to fulfil the upper and lower thresholds
620   defined for an APCG in order to be accepted as members.

621 A recruitment framework is presented where, an agro-prosumer is assessed throughout the
622 evaluation period, where his/her likelihood of meeting the APCG's pre-condition criteria and his
623 stability is estimated, and a decision is made regarding membership of an appropriate APCG.
624 Finally, a goal management framework presents an approach that determines the multiple
625 conflicting goals within the community-based production-sharing network, prioritizes the goals
626 based on their relative importance, and negotiates the goals to obtain the optimized set of goals for
627 a community-based, produce-sharing network. The proposed approach for goal management
628 assists in deciding the best priority structure. Simulation results for all three frameworks have been
629 provided to verify the proposed framework.

Acknowledgements

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646   **73**: p. 615-624.
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648

Figure 1

Theoretical foundation of APCG definition and prerequisites

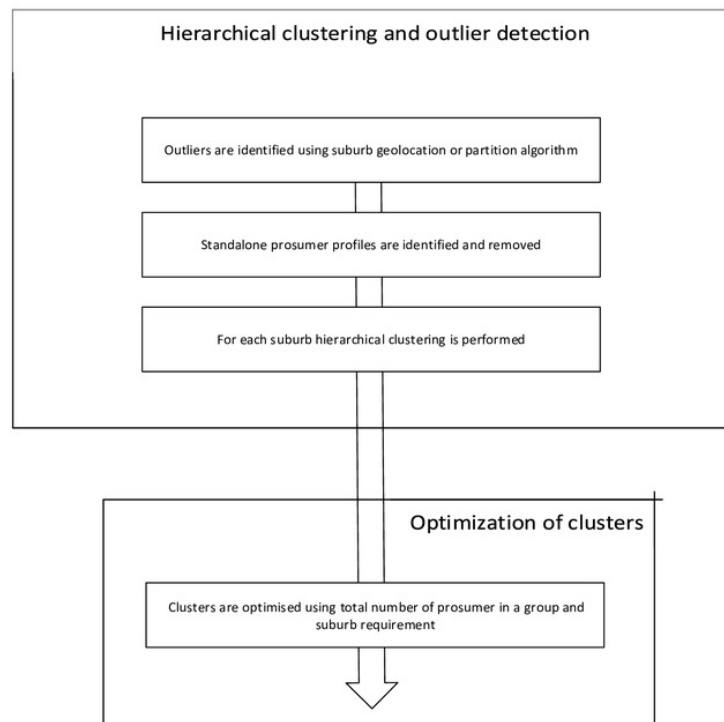



Figure 1: Theoretical foundation of APCG definition and prerequisites

Figure 2

Hierarchical clustering

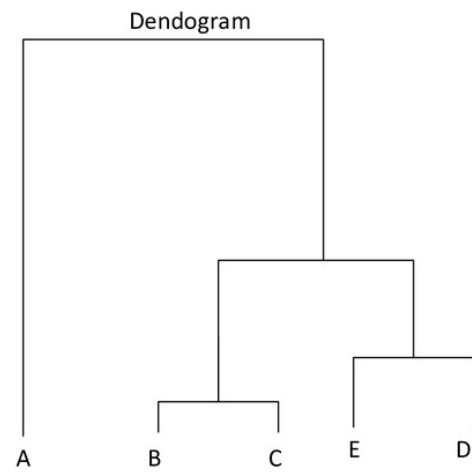



Figure 2: Hierarchical clustering

Figure 3

Flowchart for Hierarchical and Optimization of clusters

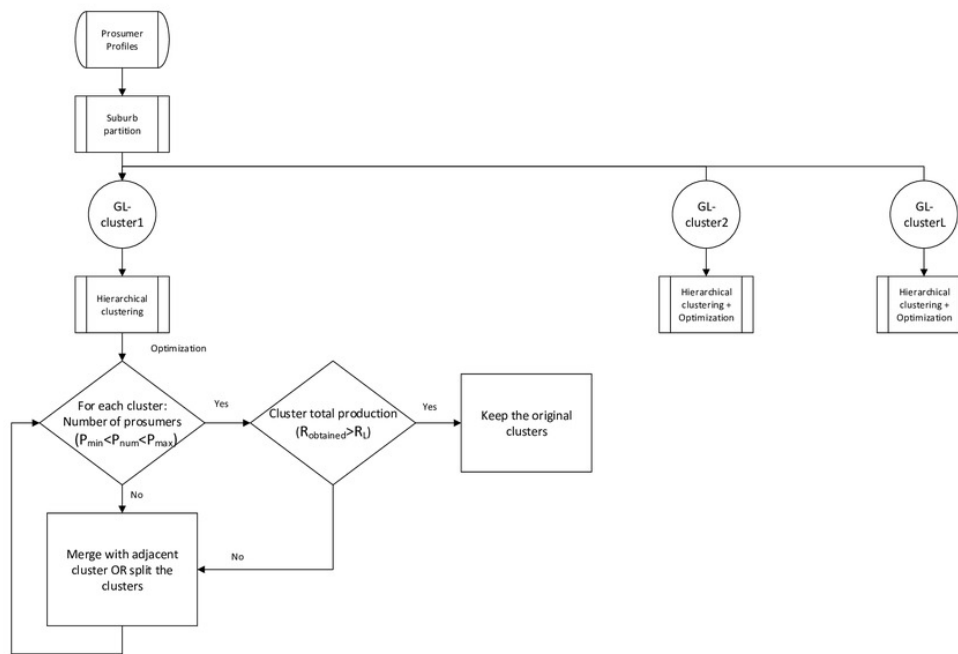



Figure 3: Flowchart for Hierarchical and Optimization of clusters

Figure 4

Overview of agro-prosumer recruitment framework

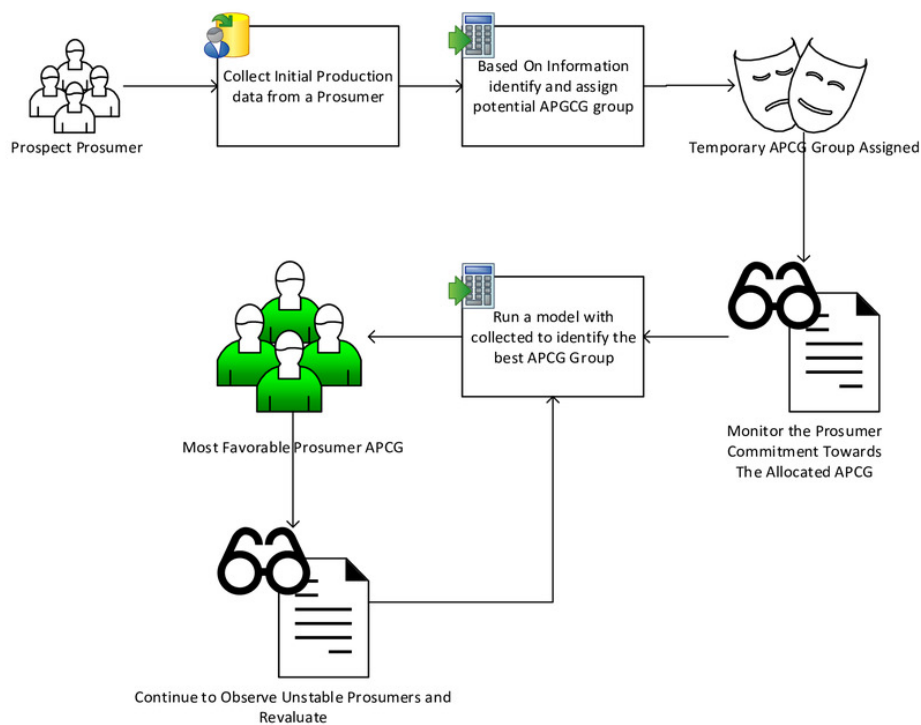



Figure 4: Overview of agro-prosumer recruitment framework

Figure 5

Approach overview to evaluate Agro-prosumer

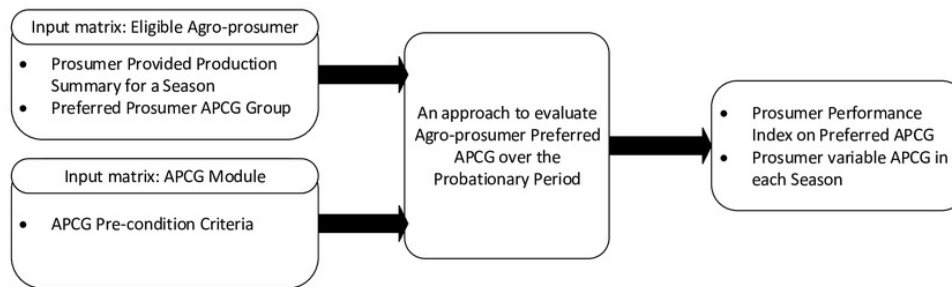



Figure 5: Approach overview to evaluate Agro-prosumer

Figure 6

New Agro-prosumer evaluation process

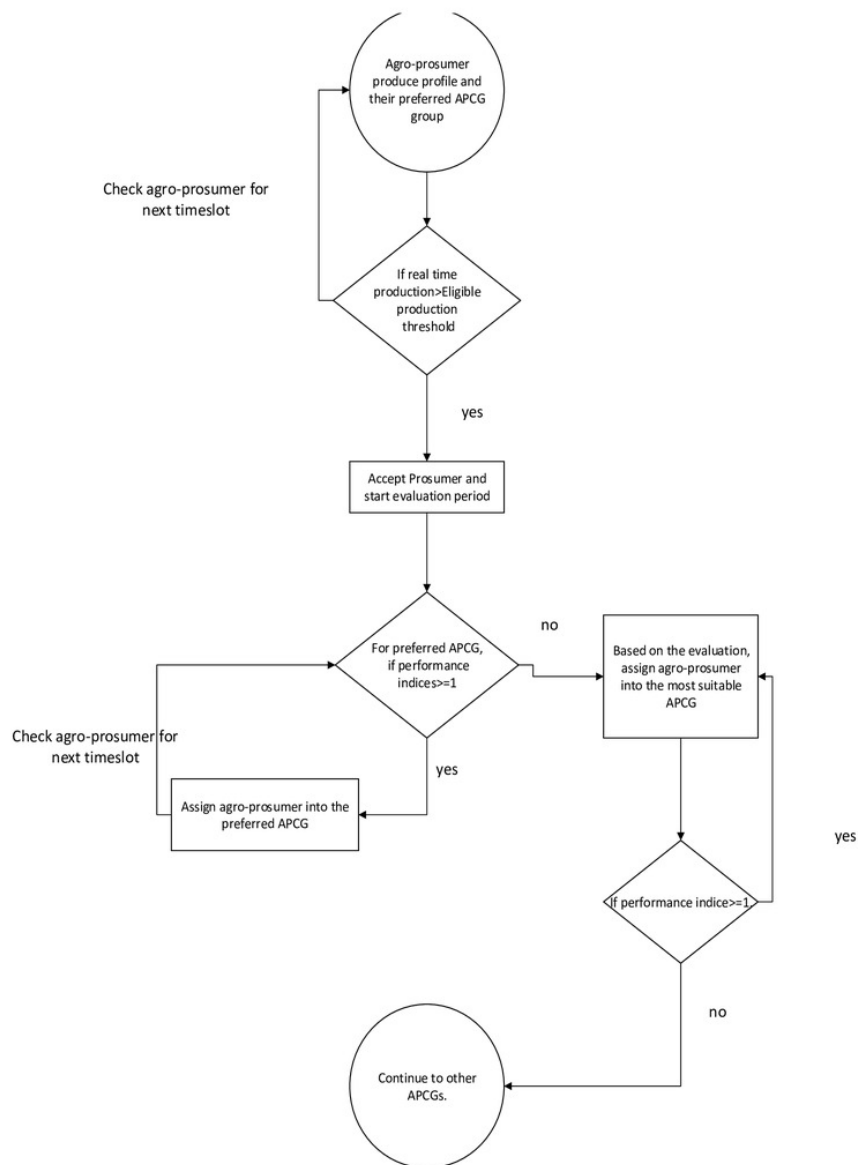



Figure 6: New Agro-prosumer evaluation process

Figure 7

Approach to determine stability index for new prosumer in APCG

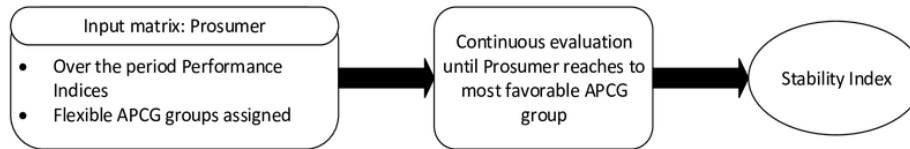



Figure 7: Approach to determine stability index for new prosumer in APCG

Figure 8

Agro-prosumer recruitment process

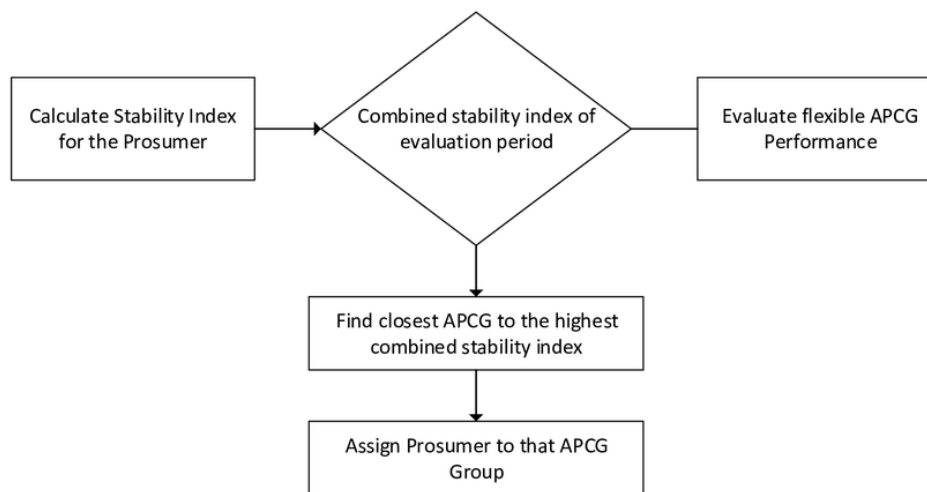



Figure 8: Agro-prosumer recruitment process

Figure 9

Concise overview of the goal management framework

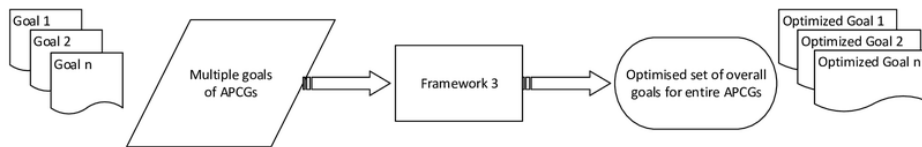



Figure 9: Concise overview of the goal management framework

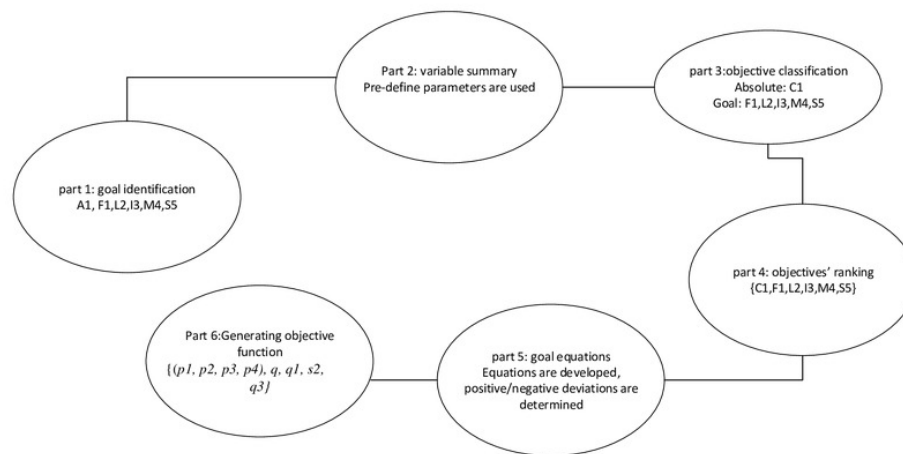
Figure 10

Goal programming model

Figure 10: Goal programming model

Partitioning algorithm for APCG's goal management

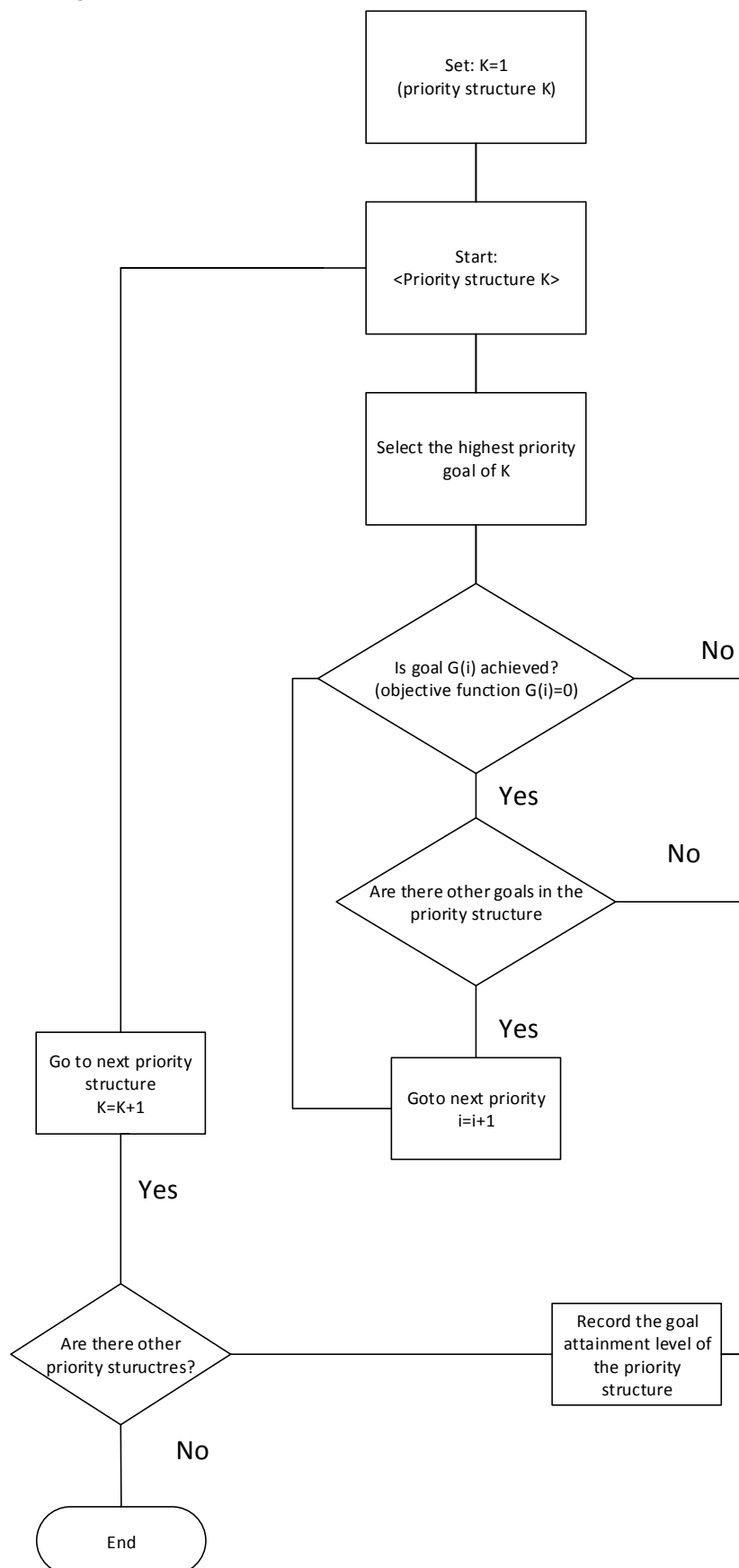



Figure 11: Partitioning algorithm for APCG's goal management

Figure 12

Prosumer dataset

Variety	Farming-method	Season	Tree-age	Family size	Consumption	Postcode	LYC	HYC	longitude	latitude
Lemon-Lisbon	organic	June-Oct	4	6	240	3143	0	360	145.0194	-37.8589
Lemon-Eureka	organic	June-Aug	4	4	160	3055	80	440	144.9422	-37.7636
Lemon-Lisbon	inorganic	June-Oct	6	2	80	3143	520	1520	145.0194	-37.8589
Lemon-Eureka	inorganic	June-Aug	5	1	40	3004	460	1460	144.9702	-37.8442
Lemon-Eureka	inorganic	June-Aug	5	3	120	3053	380	1380	144.9661	-37.8036
Lemon-Meyer	inorganic	all year	5	4	160	3206	340	1340	144.9509	-37.8465
Lemon-Lisbon	inorganic	June-Oct	6	1	40	3141	560	1560	144.9913	-37.8407
Lemon-Meyer	inorganic	all year	4	5	200	3056	100	550	144.9601	-37.7663
Lemon-Lisbon	organic	June-Oct	3	4	160	3181	0	77.6	144.9955	-37.8547
Lemon-Eureka	inorganic	June-Aug	5	1	40	3121	460	1460	145.0018	-37.8233
Lemon-Eureka	organic	June-Aug	5	2	80	3056	320	1120	144.9601	-37.7663
Lemon-Eureka	inorganic	June-Aug	5	7	280	3182	220	1220	144.9795	-37.8653
Lemon-Meyer	organic	all year	5	4	160	3181	240	1040	144.9955	-37.8547
Lemon-Lisbon	inorganic	June-Oct	6	3	120	3141	480	1480	144.9913	-37.8407
Lemon-Lisbon	inorganic	June-Oct	3	7	280	3141	0	17	144.9913	-37.8407

Figure 12: Prosumer dataset

Figure 13

Number of prosumers in each of the four clusters

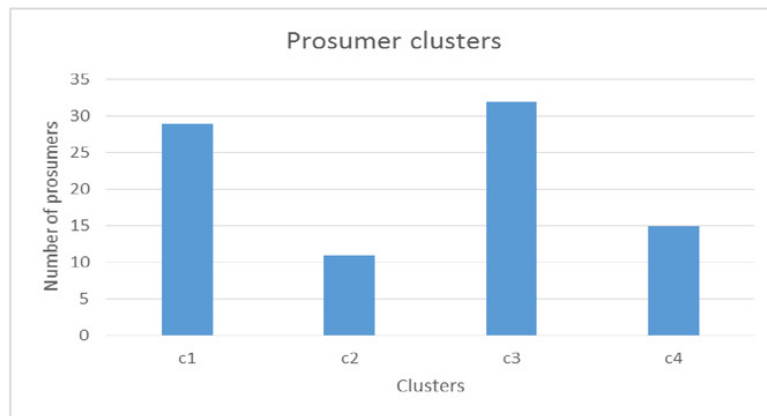



Figure 13: Number of prosumers in each of the four clusters

Figure 14

Number of prosumers in G-207 cluster

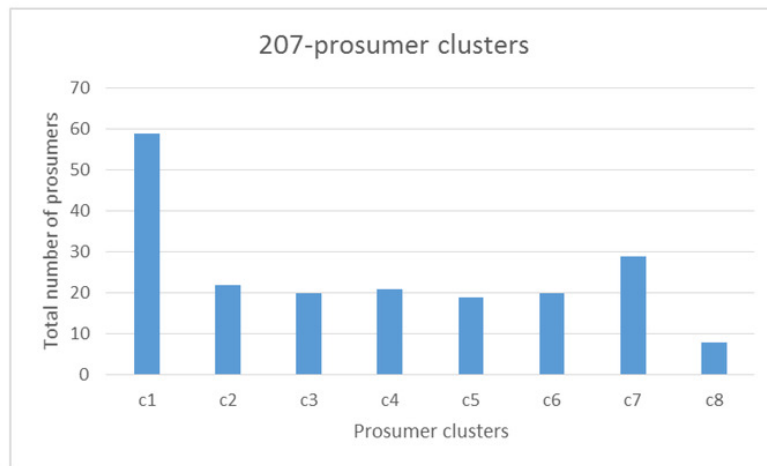



Figure 14: Number of prosumers in G-207 cluster

Figure 15

APCGs for G-206

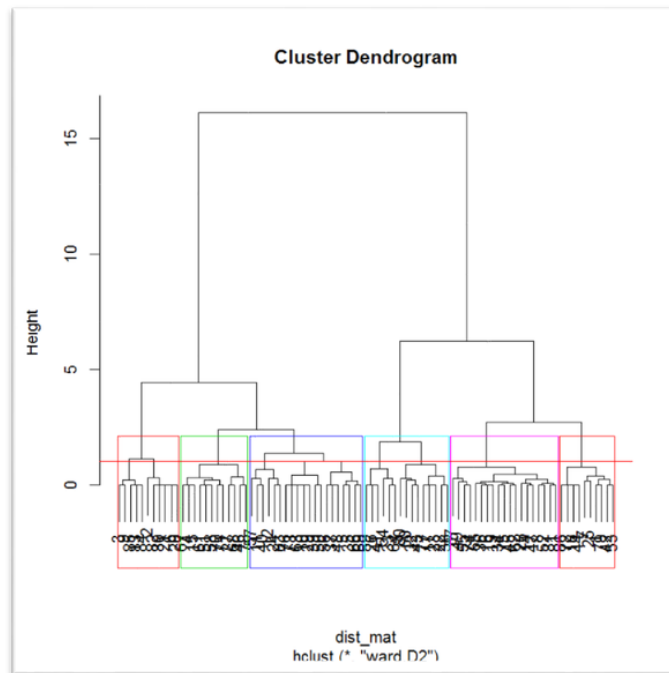



Figure 15. APCGs for G-206

Figure 16

APCG1 Agro-prosumer percentage allocated to different performance indices over the four seasons

Figure 16: APCG1 Agro-prosumer percentage allocated to different performance indices over the four seasons

Figure 17

APCG2 Agro-prosumer percentage allocated to different performance indices over the four seasons

Figure 17: APCG2 Agro-prosumer percentage allocated to different performance indices over the four seasons

Figure 18

APCG3 Agro-prosumer percentage allocated to different performance indices over the four seasons

Figure 18: APCG3 Agro-prosumer percentage allocated to different performance indices over the four seasons

Figure 19

APCG4 Agro-prosumer percentage allocated to different performance indices over the four seasons

Figure 19: APCG4 Agro-prosumer percentage allocated to different performance indices over the four seasons

Performance scale interpretation

Performance Index Interpretation	Success/Failure Rate	Performance Score
Complete Success	100%	3
Intermediate	90-99%	2
Entry	80-89%	1
Failure	0-79%	0

Table 1: Performance scale interpretation

Simulation parameters to verify APCGs definition and characteristics

Simulation parameters	Value
Numbers of prosumer profiles	200
Minimum and Maximum threshold distance for outlier detection	2km-10km
Minimum agro-prosumer participants in a group	10
Maximum agro-prosumer participants in a group	50
Minimum accumulated lemon production expected from each APCGs	50
Maximum accumulated lemon production expected from each APCGs	2000

2   Table 2: Simulation parameters to verify APCGs definition and characteristics

Parameters for generation of prosumer profile

Parameters	Value
Postcodes	Victorian
Land size	474sm
Lemon varieties	Eureka, Lisbon and Meyer
Number of trees	1
Tree age	3-6 years
Lowest production	0-50 units
Highest production	1500 units
Harvest season	Winter or Summer
Per capita consumption	40
Family size	1-7
Farming method	Organic or Inorganic

2   Table 3: Parameters for generation of prosumer profile

Hierarchical clusters for G-206

G-206				
Cluster	**Total number of Prosumers**	**LYC**	**HYC**	**Average production**
1	10	20	550	285
2	11	460	1560	1010
3	12	380	1420	900
4	20	220	1360	790
5	19	0	257	128.5
6	15	120	1000	560

2   Table 4. Hierarchical clusters for G-206

Hierarchical cluster output for G-207

G-207				
Cluster	**Total number of Prosumers**	**LYC**	**HYC**	**Average production**
1	59	0	257	128.5
2	41	320	1400	860
3	20	100	670	385
4	21	440	1560	1000
5	20	0	510	255
6	37	120	1260	690

2   Table 5 Hierarchical cluster output for G-207

Agro-prosumer community group pre-condition criteria

Agro-prosumer community groups	Total number of Prosumers	LYC	HYC	Average production
APCG1	59	0	257	128.5
APCG2	20	25	510	255
APCG3	20	100	670	385
APCG4	37	120	1260	690
APCG5	41	320	1400	860
APCG6	21	440	1560	1000

2   Table 6: Agro-prosumer community group pre-condition criteria

Simulation parameters

Simulation parameters	Value
Eligible production threshold(average)	25
Registered prosumers	50
Evaluation period	2years
APCG1	0-250
APCG2	25-550
APCG3	100-670
APCG4	120-1260

2   Table 7. Simulation parameters

Parameters for goal programming model

Simulation Parameter Yearly	Value
Average production	
Agro-prosumer community group 1 (APCG 1)	129
APCG 2	255
APCG 3	385
APCG 4	690
Available number of prosumers	
APCG 1	59
APCG 2	20
APCG 3	20
APCG 4	37
*Suburb demand (calculated for 1 suburb)	45,000
Income rate (assumed weights) APCG 1:APCG 2:APCG 3:APCG 4	1:3:6:9
Total expected Carbon token count	10
Total expected income (assumed) **	$ 11,650
Cost rate (assumed weights) APCG 1:APCG 2:APCG 3:APCG 4	1:2:3:4
Total budgeted cost constraint (assumed) ***	$ 1,000
The percentage of overall participations sustainability (Ns)	90%

2   Table 8: Parameters for goal programming model

Negotiated set of optimal goals

Goals	Details	Value
GC1	local demand of APCG	5,440
GC2	Maintain Suburb demand	45,000
GC3	Maximise the total expected income	$ 11,650
AC	Maximise carbon token	8 token/year
GC4	Minimise the cost	$ 1,000
GC5	Sustainability	90%

2   Table 9: Negotiated set of optimal goals