

1 **Development of MY FRAM matrix to assess food safety risks in horticultural crops**

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21
22 **Abstract**

23 A farm food safety risk assessment matrix (MY FRAM) was developed for horticultural farms.

24 The tool enables farmers to carry out self risk assessments on the potential of food safety risks on

25 the farm from site selection to post-harvest handling. MY FRAM was developed on Microsoft

26 ASP. NET C# 4.5 with logical functions and utilised a semi-quantitative risk assessment

27 approach (risk ranking of 1 – 9) for farmers. MY FRAM is an illustrative risk ranking tool to

28 allow farmers to quickly identify potential food safety risks and risk summary and corrective

29 actions are suggested to farms on how to reduce the risks. The tool can also be utilised as a

30 training tool for farm workers to understand the importance of food safety at the farm level.

31
32 **Keywords:** farms; fresh produce; semi-quantitative risk assessment

34 **1. Introduction**

35

36 Fresh produce and sprouted seeds have been implicated in a number of documented outbreaks of
37 illness in countries such as the US and within the EU. Powell and Chapman (2007) identified
38 that since 1990 there have been over 500 outbreaks related to produce in US and argued that
39 fresh fruits and vegetables are '*one of the most significant sources, if not the most significant*
40 *source of foodborne illness today*'. The CDC reported that the incidence of outbreaks is greater
41 for vegetables than for fruits and revealed salad greens, lettuce, sprouts, melons and tomatoes as
42 the leading vehicles of illness. These fresh products have also received much attention by the
43 FAO/WHO, which gave leafy green vegetables (including fresh herbs) the highest priority as
44 commodities of global concern. Many of these commodities are vulnerable to contamination
45 because they grow on or close to soil where contamination can potentially occur. Produce can
46 also become contaminated with microbial pathogens by a wide variety of mechanisms.
47 Contamination leading to foodborne illness has occurred during production, harvest, processing,
48 and transporting, as well as in retail and foodservice establishments and in the home kitchen
49 (FDA, 2010).

50

51 The likelihood of the edible parts of a crop becoming contaminated depends upon a number of
52 factors which includes growing location, type of irrigation application and nature of produce
53 surface. Some of the sources of pre-harvest contamination of produce include irrigation water
54 (Steele and Odumeru, 2004), contaminated manure, sewage sludge, run-off water from livestock
55 operations and wild and domestic animals (Beuchat, 2006; Delaquis, Bach and Dinu, 2007).

56

57 It is imperative to start reducing risk factors at farms, so this may reduce the contamination load
58 into the processing and food preparation stage. A farm food safety risk assessment may be one of
59 the many intervention strategies in reducing or preventing the food safety and disease risks from
60 occurring. Hence, the development of MY FRAM is timely and can be utilised by horticultural
61 farmers to identify potential food safety risks and to develop action plans or corrective actions.

62

63 **2. Methods**

64 **2.1 Development of MY FRAM matrix**

65 **2.1.1 User interface**

66

67 MY FRAM was developed using Microsoft ASP. NET C# 4.5 version framework and utilised
68 standard mathematical and logical functions to calculate the risks. The database portion was
69 handled using Microsoft SQL Server 2014 Express edition. To ease the development, Microsoft
70 Language Integrated Query, or better known as LINQ was used to establish the connection
71 between web application and database. On top of that, Microsoft AJAX Control Toolkit was also
72 used to enable asynchronous communication between certain functions in MY FRAM to enhance
73 users' experience. Users can go to <http://umk.applyit.com.my> and click on "Sign up new
74 account" to register. Once registered as user, user can select go to Project > Create Project. Users
75 are then prompt to name and describe the project. When a project has been created successfully,
76 user will be allowed to add new Study into the project based on a period of time. After naming
77 the study, users can go through the process to assess the risks for their crops.

78

79 The development and improvement of the MY FRAM matrix is similar to the Level 1 risk
80 ranking proposed by van Gerwen et al. (2000) and the spreadsheet model of Soon et al. (2013)
81 and Ross and Sumner (2002) but it estimates the risks according to the farm process flow (e.g.
82 from site selection to harvest).

83

84 **2.2 Delphi-based approach**

85 **2.2.1 Sampling and selection of experts**

86

87 Expert panels were invited (Valeeva, Meuwissen, Oude Lansink, &Huirne, 2005) to take part in
88 the Delphi study to identify and select the most relevant food safety hazards (and diseases)
89 occurring at the fresh produce farms in UK. Here, the panellists were not selected randomly, so
90 representativeness is not assured. The selection of experts for the Delphi study was made
91 through:

92

- 93 • Personal contacts of the author and the research supervisory committee made in the
94 course of the farm food safety research
- 95 • Participants in international food safety conferences
- 96 • Experts co-nominated by others (Scapolo&Miles, 2006)

97

98 A total of 86 experts on fresh produce safety were contacted and invited to participate in the
99 Delphi survey. Sixteen percent of the invited experts responded to the Delphi survey. The
100 reduced response rates is typical of Delphi studies as carried out by Grundy and Ghazi (2009),
101 Stark et al. (2002) and Wentholt et al. (2010).

102 Experts were defined as having met two criteria: (1) currently teaching in a university level food
103 science or agriculture/horticulture programme or working in the horticulture/agriculture (2)
104 experience in the food safety, microbiology, chemical, toxicology, or risk assessment. The
105 invitation contained a cover letter of a short description of the study and Delphi Round II
106 questionnaire. Even though it is more advantageous to conduct a face to face interview in the
107 first round to increase the response rates, it was not conducted in this study due to the limited
108 financial resources and time. Three rounds of questions and answers were deemed to be optimal
109 for this study (Soon et al. 2012):

110

111 Round (I) Review and collate potential farm food safety hazards occurring in fresh
112 produce farms

113 Round (II) Experts' ranking of food safety hazards

114 Round (III) Review feedback from Round II (and revise if necessary), review MY
115 FRAM and suggest for improvements

116

117 **2.3 Testing of MY FRAM matrix on farms**

118 MY FRAM (spreadsheet version; Soon et al. 2013) was tested in 12 UK fresh produce farms.

119 The on-farm visit was conducted in 4 steps and a total duration of 3 hours was targeted. Steps

120 included (i) interview with the farmer or technical/farm manager to gather farm food safety

121 practices data, (ii) briefing and explanation of MY FRAM, (iii) Testing of MY FRAM and

122 collecting feedback from farms, and (iv) tour of farm and facilities with farmer.

123

124 **3. Results and Discussion**

125 **3.1 Good Agricultural Practice (GAP) analysis**

126 Most risk based models and standards for managing food safety at the farm level rely on the
127 adoption of Good Agricultural Practice (GAP), therefore MY FRAM matrix required appropriate
128 GAP to be embedded. The Good Agricultural Practice (GAP) Analysis self-assessment questions
129 were developed for fresh produce production to encourage farmers to assess specific process
130 during the primary production. A check-list containing 38 questions was drawn up according to
131 Good Agricultural Practice (with an emphasis on food safety) and distributed under 8 sections
132 according to the production process and inputs: (1) Process – Site selection; (2) Process –
133 Seed/transplants; (3) Process – Sowing/planting; (4) Process – Crop harvest; (5) Process – Post-
134 harvest handling; (6) Input – Irrigation water (Figure 1); (7) Input – Fertilizers and (8) Input –
135 Pesticides (Knight 2009; Rangarajan et al. 2000). Figure 1 shows a snapshot of the self-
136 assessment based on Good Agricultural Practices. Figure 1 does not illustrate GAP but was
137 designed in a question and answer format to allow farmers to conduct their own self risk
138 assessment of their current farm situation. These 38 questions were drawn up based on
139 commercial systems such as GlobalGAP, Tesco Leafy Crop Assessment, Safeproduce.eu and
140 FDA Produce Rule. The questions were selected on the basis of occurrences of potential hazards
141 at the farm level and these 38 questions were summarised in order to allow farmers to focus on
142 basic fresh produce safety criteria. A number of questions (> 40) may be too distracting for the
143 farmers, while too few questions may not provide enough resolution for the farmers to conduct
144 appropriate self-assessments. A more comprehensive and shorter version of assessment questions
145 is more suited for small and medium farmers to enable them to focus their resources in
146 prioritising food safety.

147

148 Figure 1. Self Risk Assessment (Question and Answer format) of Good Agricultural Practices

149

150 **3.2 Process Flow**

151 MY FRAM is then divided into different process flow ranging from site selection to postharvest
152 handling and inputs such as irrigation water, application of fertilisers and pesticides. According
153 to the processes, users are given scenarios of likelihood of occurrences (high, medium, low or no
154 defined risk) to select from. For example, the risk factor for irrigation water sources is described.
155 The low likelihood of occurrence for potential hazards to arise is defined as fresh produce farms
156 using borehole/ground water or using tested (safe) surface water while higher likelihood of
157 occurrence of food safety problems is associated with the use of surface water (Figure 2) with
158 possible livestock access.

159

160 Figure 2. Example of likelihood scoring for ‘source of irrigation water’

161

162 Farmers use MY FRAM based on their own judgment while assessing the likelihood of
163 occurrences. Examples are given to enable users to select and determine the likelihood of
164 selected/certain food safety hazards that could occur on their farms.

165 Risks are assessed on the probability of future occurrence; how likely is the risk to occur?
166 How frequently has this occurred? (HSE 2008) Likelihood of occurrence is divided into low (1),
167 medium (2) and high (3).

168

169 The criteria to help farmers to assess the likelihood of occurrence are:

170 *High* (3): This hazard has caused outbreak/recall on my farm

171 *Medium* (2): This outbreak/contamination has been reported in the local
172 media or had occurred in other nearby farms

173 *Low* (1): Never occurred, but likelihood of occurrence is possible

174

175 **3.3 Severity of food safety hazard**

176 Criteria for the definition of each level of severity scoring for each risk factor were based on the
177 review of literature and food legislation, vetted by consensus expert opinion from academia and
178 industry experts.

179

180 The severity scoring is based on the following parameters (for general population unless
181 stated otherwise):

182 *Minor* : Minor injury to consumer

183 *Moderate* : Consumer in hospital/Serious short term injury

184 *High* : May lead to severe health impact or death

185

186 **3.4 Risk weight (severity \times likelihood)**

187 A risk matrix is developed to measure risk. The determination of risk is derived by multiplying
188 the scores assigned for likelihood of occurrences and the severity of the hazards. The risk matrix
189 consists of a 3 x 3 matrix of likelihood (high, medium and low) and severity (high, medium and
190 low) to keep the risk assessment as simple as possible for farm operators' usage (Figure 3).

191 There are other matrixes which use 4 x 4 or a 5 x 5 matrix depending on the risk assessor's
192 requirements. According to Moses and Malone (2005), a typical 3 x 3 matrix do not provide

193 enough resolution, while anything greater than a 5 x 5 was too distracting. This 3 x 3 matrix is
194 adopted for its simplicity in translating practical risk ranking outputs for farm personnel.

195
196 The overall food safety risk can be categorised into high, medium or low based on the risk
197 ranking score (1-9) when likelihood score multiplies with severity score. The scores used in
198 FRAM matrix were based on a simple 1 to 9 scoring system to retain simplicity.

- 199 - Low risk (1-3)
- 200 - Medium risk (3-5)
- 201 - High risk (6-9)

202
203 Figure 3. Food safety risk (Risk weight) = Likelihood of occurrence × Severity of food safety
204 hazard

205 **3.5 Results presentation**

206
207 The farm food safety risk assessment results is summarised in a tabular and radar format (Figure
208 4). First, the likelihood assessments are scored by the users based on their experiences and farm
209 specificity. The relative ranking of risk scores will help farms to prioritise and optimize the
210 allocation of resources or to request for technical assistance to reduce the likelihood of food
211 safety hazards and diseases from occurring. However, the risk scores generated by the MY
212 FRAM should be interpreted with caution. This is due to the generic nature of the tool and
213 uncertainty associated with risks.

214
215 Figure 4. Example of results shown in radar chart format

216

217 **3.6 Development of action plan and control measures**

218 From the risk ranking output, farmers are then guided to develop their own action plan for
219 improvement and control measures (Figure 5) are suggested according to Good Agricultural
220 Practices section (HSE 2006; Knight 2009).

221

222 Figure 5. Action plan and corrective actions

223

224 **3.7 Effectiveness as judged by the end user**

225 End users (farmers) were asked to determine which part of the tool and topics were most useful
226 or relevant to them. Developing their own action plan and using it as proof of assessment for
227 future third-party audits were ranked the highest among the farms (Fig. 6). All the farms also
228 agreed that ‘Sowing/Planting’ and ‘Irrigation Water’ topics were the most relevant and useful to
229 them followed by ‘Plant Protection Products’ (92%) and ‘Harvesting’ (92%). A few topics such
230 as waste handling and on-site packing (e.g. harvesting and bagging of fresh produce on rigs)
231 were suggested to be included into MY FRAM. *Farm B* also stated that there should be less
232 focus on wild animals’ assessment. Instead, more emphasis should be given to pesticides
233 assessment as well as to expand the post-harvest handling assessment into individual washing,
234 grading and packing assessments. *Farm C* noted that MY FRAM should specify the type of
235 crops and risks of specific crops, e.g. Group I – leafy greens, tomatoes; Group II – carrots,
236 onions; Group III – potatoes and Group IV – wheat, sugarbeet. More than half of the farms
237 (58%) revealed that MY FRAM matrix has increased their interest in conducting farm food

238 safety-risk assessment and 45% stated that after testing and using MY FRAM, it has improved
239 their farm-food safety practices knowledge.

240

241 Figure 6. Most useful / relevant part of MY FRAM matrix (n=11 farms)

242

243 **4. Role of MY FRAM in horticultural crops**

244 The semi-quantitative scoring system of MY FRAM matrix to characterise risk is a good
245 approach to help growers to understand that certain practices can be dangerous (e.g. surface
246 water accessible by livestock). MY FRAM matrix can provide growers with a simpler means of
247 assessing the level of produce safety in their farm based on general GAP requirements. Industry
248 and/or commodity specific audits are extensive and costly and guidance from tools such as MY
249 FRAM, Safeproduce.eu (<http://www.safeproduce.eu/Login.aspx?ReturnUrl=%2fDefault.aspx>)
250 and the proposed rule for Standards for the Growing, Harvesting, Packing, and Holding of
251 Produce for Human Consumption (FDA, 2014) will facilitate farmers in identifying potential risk
252 factors. The choice of food safety risk assessment model / matrix / tool is crucial to an
253 organisation and MY FRAM can be utilised as a mechanism for assessing food safety risks and
254 is an optional choice of self-risk assessment for farmers (Manning and Soon, 2013).

255

256 **5. Limitations of MY FRAM**

257 The general GAP requirements will be similar for all farms but some growers will require a more
258 specialised GAP approach depending on their commodity or target consumers. In order to keep
259 MY FRAM simplistic and to encourage farmers to carry out self-risk assessments; some of the
260 risk factors were not specific enough and options given were limited, e.g. under risk factor for

261 site selection: ‘Probability of site contaminated with run-offs from livestock farms’. Three
262 scenarios likelihood of occurrences were given: (i) My farm is upstream from any sources of
263 contamination; (ii) My farm is downstream from a well-managed livestock farm but may receive
264 run-off during flooding; and (iii) My farm is downstream from at least one livestock farm and
265 run-offs are commonly received. Since different farms faced different geographical
266 environments, the options or scenarios given may not be specific enough for farms to select
267 from. Hence this causes the farms to prompt further ‘what if’ questions – such as ‘What if I’m
268 using borehole water and my neighbouring farm is a well-contained livestock farm?’ When using
269 MY FRAM, farmers are provided with a guide to determine the level of risks involved in
270 different processes.

271

272 **6. Conclusion**

273 MY FRAM matrix can be described as an illustrative risk ranking tool to facilitate horticultural
274 farmers to identify potential risk factors during their crop production. It is best suited for small
275 and medium enterprises (SMEs) to encourage farmers to identify food safety hazards and to help
276 develop appropriate action plan for improvement. MY FRAM is a combination of semi-
277 quantitative (matrix) and value-based criteria (based on farmers’ judgement of likelihood and
278 experiences) to assess risks. An on-farm food safety risk assessment tool may be timely to
279 encourage farms to assess potential hazards and to train both full-time and seasonal farm
280 workers. MY FRAM focuses on risk reduction and not risk elimination.

281

282 **Acknowledgement**

283 The authors gratefully acknowledge the financial support from the Ministry of Education
284 Malaysia (R/RAGS/A07.00/00295A/001/2013/000120). The funder played no role in study
285 design, collection, analysis, interpretation of data, writing of the report or in the decision to
286 submit the paper for publication.

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Figure Captions

Figure 1. Self-Risk Assessment (Question and Answer format) of Good Agricultural Practices

Figure 2. Example of likelihood scoring for ‘source of irrigation water’

Figure 3. Food safety risk (Risk weight) = Likelihood of occurrence × Severity of food safety hazard

Figure 4. Example of results shown in radar chart format

Figure 5. Action plan and corrective actions

Figure 6. Most useful / relevant part of MY FRAM matrix (n=11 farms)

CROP INPUTS: IRRIGATION WATER

Identify source of irrigation water?
 Is it surface water or ground water? Typical sources of agricultural water include flowing surface waters from rivers, streams, irrigation ditches and open canals; impoundments such as ponds, lakes, and reservoirs; groundwater from wells and municipal supplies. It is generally assumed that groundwater is less likely to be contaminated with high levels of pathogens than surface water. (FDA 1998). After identifying your water source, you can prepare a water system description. This description can use maps, photographs, drawings or other means to communicate the location of the water sources and flow of water (LGMA 2010).

Does irrigation water pass by animal farms / sewage sites / industrial areas?
 Topological elements surrounding the water source such as slopes or depressions, could lead to the introduction of runoff from an adjacent field, grazing land, animal production facility, septic system, waste spreading field, dairy lagoon or other potential sources of pathogen contamination. Runoff prevention and diversion structures, such as diversion beams and vegetated buffer areas can help divert runoff away from water source (Sutlow 2003).

Is contact minimised between irrigation water and the edible plant parts?
 Irrigation procedures that expose produce to contaminated water increase the risk of microbial contamination, especially if irrigation takes place close to harvest. In order to reduce the risk, it is important to minimise direct contact between irrigation water and produce within the period when survival of pathogens could be expected. This includes favouring drip or furrow irrigation over spray irrigation.

Is the water source protected from run-off and flooding?
 Water sources for crop irrigation can be either surface water sources or ground water. Prevention of water contamination is top priority in every basic safety plan because once contaminated, water can be difficult to clean up. Topological elements surrounding the water source such as slopes and depression may lead to flooding or run-off from an adjacent field. This, in turn, may lead to the introduction of contamination from the adjacent field. Run-off structures, waterways, diversion beams and buffer areas may be able to divert run-off away from surface water sources or a well. Be sure that well casings extend more than 12 inches above the land surface, and that flood water does not reach the well. Observe the local rain patterns to determine its effect on run-off from adjacent farms or animal feeding operations to your water source.

Is water source protected from animal contamination?
 Animal production nearby may pose risks due to the high volume of animal waste or the possibility of animal grazing near the water source. Wild animals may pose the same contamination risks as domestic or farm animals. Recommendations for the distance between potential contaminants and a water source range from 30 to 400 feet. Growers should take the risks of the potential contaminant into consideration when deciding how far away a well should be situated from a potential source of contamination. If possible, wells should be located in an elevated area that is up-hill of potential sources of contamination.

Is irrigation water sent for microbiological test?
 Growers may elect to test their water supply for microbial contamination on a periodic basis using standard indicators for faecal pollution. Faecal coliform can be used as a reasonably reliable indicator of bacterial pathogens, as their environmental survival characteristics and rates of removal or die-off in treatment processes are broadly similar. However, bacterial safety of water does not necessarily indicate the absence of protozoa and viruses. Where water sources come from public sources, information on microbial analysis the water may be available from the local water authority. Water quality, especially surface water quality, can vary with time (e.g. seasonally or even hourly) and a single test may not indicate the potential for water to be contaminated. Furthermore, testing water may not reveal specific pathogens if they are present in low numbers. However, appropriate microbiological testing may be useful for confirming water quality concerns in extreme situations (e.g. polluted water source) and in assessing the effectiveness of certain control programmes (e.g. clean-up of tank water).

CATEGORY	IRRIGATION CONDITIONS	EXPOSED GROUP	INTESTINAL NEMATODES ^a (ARITHMETIC MEAN NO. OF EGGS PER LITRE) ^c	Faecal COLIFORMS (PER 100 ML) ^e
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks ^d	Workers, consumers, public	1	1000 _g
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees ^e	Workers	1	No standard recommended
C	Localised irrigation of crops in category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable

a. In specific cases, local epidemiological, socioeconomic and environmental factors should be taken into account, and the guidelines modified accordingly.
 b. Ascariis and Trichuris species and hookworms.
 c. During the irrigation period.
 d. A more stringent guideline, (200 faecal coliforms per 100 ml) is appropriate for public lawns, such as hotel lawns with which public may come into direct contact.
 e. In the case of fruit trees, irrigation should cease two weeks before fruit is picked and no fruit should be picked off the ground.

Source: WHO (1999)

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Figure 1. Self-Risk Assessment (Question and Answer format) of Good Agricultural Practices

Edit Study

Information | Site Selection / Managements | Seeds / Transplants | Sowing / Planting | Crop Harvest | Postharvest Handling | **Irrigation Water** | Application of fertiliser | Pesticides | Result

Is cooling medium maintained properly?
 Does irrigation water pass by animal farms / sewage sites / industrial areas?
 Is contact minimised between irrigation water and the edible plant parts?
 Is the water source protected from run-offs and floods?
 Is water source protected from animal contamination?
 Is irrigation water sent for microbiological tests?
 Are wells constructed normally for water protection?
 How often to test for water quality and what to test for?

Source of irrigation water (for RTE crops)

Potable water or underground water
 Tested (safe) surface water
 Untested surface water

Probability of site contaminated with run-offs (especially pesticide run-offs) from other arable/horticulture farms

My farm is upstream from any sources of contamination

Method of Irrigation

Furrow or drip or types of irrigation where edible parts of crops are not contacted by water

HAZARD AND RISK WEIGHTING	CODE	LIKELIHOOD SCORING	SEVERITY SCORING	RISK WEIGHT (LIKELIHOOD * SEVERITY)	RISK RANKING
Potential microbiological hazards (if using surface water; likelihood of contamination with pathogens is higher)	A	1	3	3	Low Risk
Microbiological hazard (Potential contamination of irrigation water from run-offs, animal faeces. E.g. E. coli O157:H7, Salmonella spp., microbes from sewage sludge)	B	1	3	3	Low Risk
Chemical hazard (Potential contamination of irrigation water from excessive pesticide due to run-offs from other farms)	C	1	3	3	Low Risk
Microbiological hazard (potential contamination from irrigation water in contact with edible parts of crops).	D	1	3	3	Low Risk

376
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Source of irrigation water (for RTE crops) Likelihood scoring

Potable water or underground water	1
Tested (safe) surface water	2
Untested surface water	3

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Figure 2. Example of likelihood scoring for ‘source of irrigation water’

Edit Study

Information | Site Selection / Managements | Seeds / Transplants | Sowing / Planting | Crop Harvest | Postharvest Handling | **Irrigation Water** | Application of fertiliser | Pesticides | Result

Is cooling medium maintained properly?
 Does irrigation water pass by animal farms / sewage sites / industrial areas?
 Is contact minimised between irrigation water and the edible plant parts?
 Is the water source protected from run-offs and floods?
 Is water source protected from animal contamination?
 Is irrigation water sent for microbiological tests?
 Are wells constructed normally for water protection?
 How often to test for water quality and what to test for?

Source of irrigation water (for RTE crops)

Potable water or underground water
 Tested (safe) surface water
 Untested surface water

Probability of site contaminated with run-offs (especially pesticide run-offs) from other arable/horticulture farms

My farm is upstream from any sources of contamination

Method of Irrigation

Furrow or drip or types of irrigation where edible parts of crops are not contacted by water

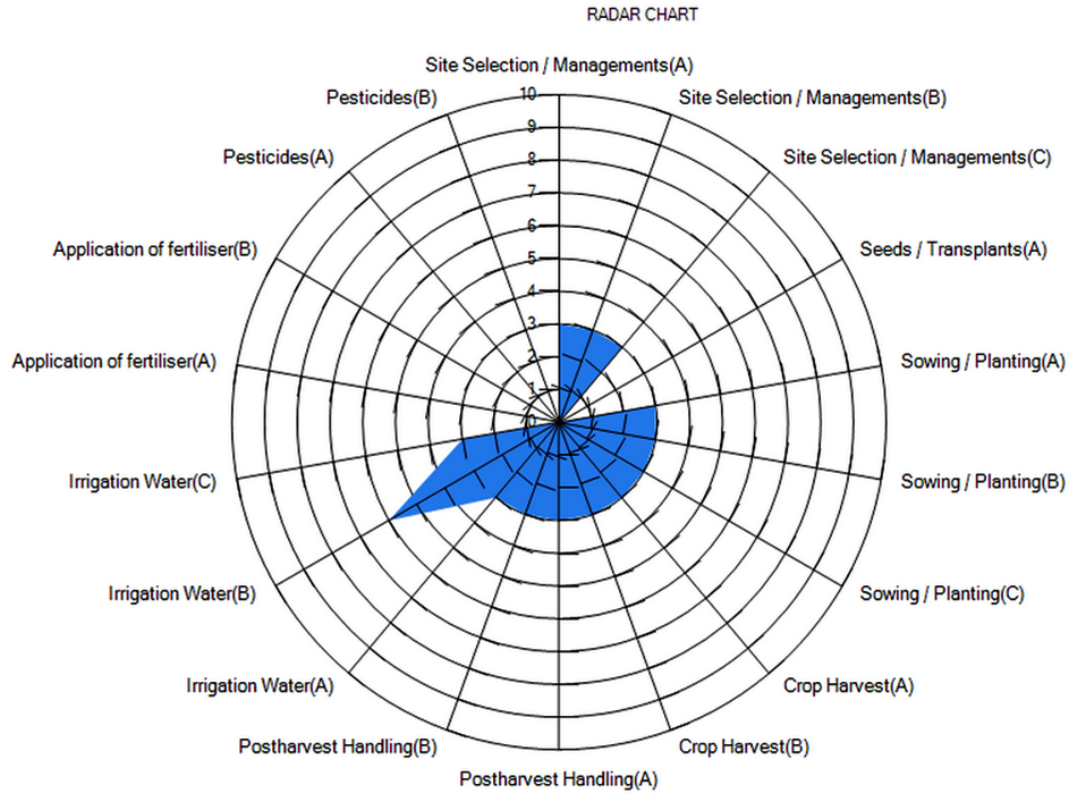
HAZARD AND RISK WEIGHTING	CODE	LIKELIHOOD SCORING	SEVERITY SCORING	RISK WEIGHT (LIKELIHOOD * SEVERITY)	RISK RANKING
Potential microbiological hazards (if using surface water; likelihood of contamination with pathogens is higher)	A	1	3	3	Low Risk
Microbiological hazard (Potential contamination of irrigation water from run-offs, animal faeces. E.g. E. coli O157:H7, Salmonella spp., microbes from sewage sludge)	B	1	3	3	Low Risk
Chemical hazard (Potential contamination of irrigation water from excessive pesticide due to run-offs from other farms)	C	1	3	3	Low Risk
Microbiological hazard (potential contamination from irrigation water in contact with edible parts of crops).	D	1	3	3	Low Risk

382
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Source of irrigation water (for RTE crops)	Likelihood scoring	Severity scoring	Likelihood x severity scoring	Risk weight	Risk ranking
Potable water or underground water	1	3	1 x 3	3	(1 – 3) low
Tested (safe) surface water	2	3	2 x 3	6	(4 – 6) medium
Untested surface water	3	3	3 x 3	9	(6 – 9) high

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Figure 3. Food safety risk (Risk weight) = Likelihood of occurrence × Severity of food safety hazard



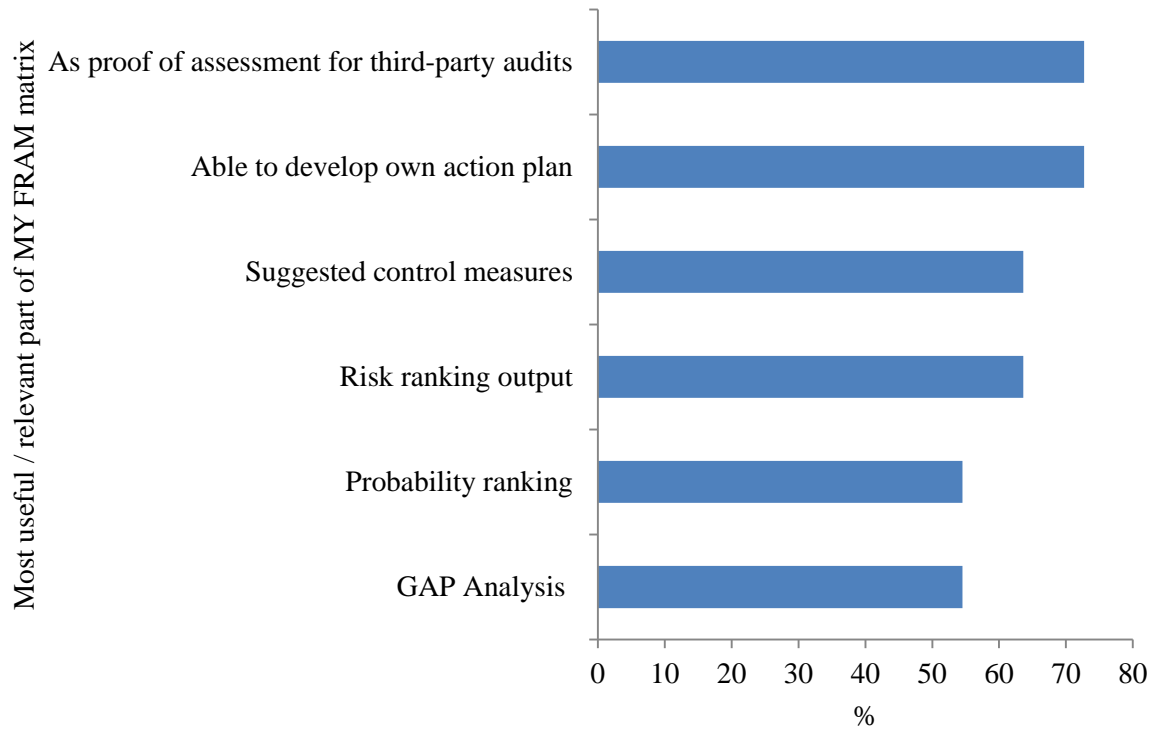
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Figure 4. Example of results shown in radar chart format

Irrigation Water			
Microbiological hazard (Potential contamination of irrigation water from run-offs, animal faeces. E.g. E. coli O157:H7, Salmonella spp., Cryptosporidium parvum, Giardia intestinalis, Cyclospora cayatanensis, norovirus)	1 to 3	Low Risk	Well done. The risks posed to consumers from microbial contamination of your crop are low. Keep up with the good agricultural practices and HACCP based risk assessments conducted on your farm.
	4 to 6	Medium Risk	The risks posed to consumers from microbial contamination of your crop is medium. They could be further reduced by considering: i. Runoff prevention and diversion structures, such as diversion beams and vegetated buffer areas can help divert runoff away from water source; ii. Minimise direct contact between irrigation water and produce within the period when survival of pathogens could be expected; iii. Wells should be located in an elevated area that is up-hill of potential sources of contamination; iv. Growers may elect to test their water supply for microbial contamination on a periodic basis using standard indicators for faecal pollution.
	7 to 9	High Risk	The risks posed to consumers from microbial contamination of your crop is high. They could be further reduced by considering: i. Runoff prevention and diversion structures, such as diversion beams and vegetated buffer areas can help divert runoff away from water source; ii. Minimise direct contact between irrigation water and produce within the period when survival of pathogens could be expected; iii. Wells should be located in an elevated area that is up-hill of potential sources of contamination; iv. Growers may elect to test their water supply for microbial contamination on a periodic basis using standard indicators for faecal pollution.
Chemical hazard (Potential contamination of irrigation water from excessive pesticide due to run-offs from other farms)	1 to 3	Low Risk	Well done. The risks posed to consumers from chemical contamination of your crop are low. Keep up with the good agricultural practices and HACCP based risk assessments conducted on your farm.
	4 to 6	Medium Risk	The risks posed to consumers from chemical contamination of your crop is medium. They could be further reduced by considering: i. Using a plant strip or buffer to reduce potential of run-offs from other farms' areas to reduce pesticide run-offs; ii. Check the pesticide application procedure and training.
	7 to 9	High Risk	The risks posed to consumers from chemical contamination of your crop is high. They could be further reduced by considering: i. Using a plant strip or buffer to reduce potential of run-offs from other farms' areas to reduce pesticide run-offs; ii. Check the pesticide application procedure and training.

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Figure 5. Action plan and corrective actions



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Fig.6. Most useful/relevant part of MY FRAM matrix (n=11 farms)

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