THE SOCIAL FACTORS THAT AFFECT THE ADOPTION OF BMPS IN AGRICULTURE

ABSTRACT

A large amount of research goes into determining the best practices for farming and the environment. This scoping review examines the social factors affecting the adoption of best management practices (BMPs) by farmers that could mitigate an environmental issue like climate change, water quality, soil quality and erosion, or the loss of biodiversity. In 17 papers about social factors that affect adoption, the qualitative analysis of barriers and enablers to adoption led to their categorization into four themes: “Farm Management”, “Economic”, “Government”, and “Social” factors. It was found that the communication, relationships, and trust between farmers and information providers was not included in most studies despite being related to other important factors like farmer networks, government programs and policies, and cost. Future research should consider how all factors work together to act as barriers or enablers. Also, the distribution of information in these papers, if mentioned at all, was a top-down linear model. Going forward, a “loop” model of communication that allows for feedback from farmers so their needs and concerns are met could be a more effective approach for information providers to encourage the adoption of BMPs by farmers.

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1. Introduction

The impact of unsustainable agricultural practices on the environment are diverse and includes soil degradation, water quality concerns and the loss of biodiversity. Climate change is real, and the effects can already be experienced through extreme flood events, extreme heat, and massive storms. Agriculture is crucial for our society but the way we farm has become damaging to the Earth and a strong push towards sustainable agriculture is needed immediately. Best Management Practices (BMPs) are evidence-based and provide farmers with guidelines for sustainable practices. Examples of BMPs include growing cover crops to protect soil on fields that would otherwise lay bare and exposed until next season, timing fertilizer application to reduce waste and runoff into nearby water systems and maintaining diverse habitat on the field edges to increase the biodiversity of native species that use the land and create wildlife corridors. In Canada, the provincial and federal agriculture ministries identify additional relevant BMPs and provide information to farmers to support their implementation (Agriculture and Agri-Food Canada 2021a, Ministry of Agriculture, Food, and Rural Affairs 2021). Learning how BMP information is being communicated to agriculture growers in high-income countries and whether the farmer is receiving and applying the information will help determine how adoption can be encouraged in Canada.

Knowler and Bradshaw's 2007 review of agriculture adoption literature from around the world provides recommendations for the creation of effective policies to encourage the adoption of BMPs. Through analysis of 23 studies, they identified 46 variables that correlated to the adoption of BMPs and categorized them into four groups: Farmer and Farm Characteristics, Farm Biophysical Characteristics, Farm Financial/Management Characteristics, and Exogenous Factors. This is a keystone paper that has influenced subsequent studies which have built on their

work, with most focusing on the socio-economic factors influencing the adoption of BMPs in agriculture, such as farmer's age, farm acreage, education level, and family income. Social factors such as farmer's identity, attitude, perceptions, and social groups must be analyzed as well to develop a more nuanced understanding of the complex decision-making processes of farmers (Foguesatto, et al. 2020). Baumgart-Getz et al (2012) found social factors to be insignificant influencers for adoption of BMPs when studied individually and suggests clustering social factors together to increase their effectiveness.

There is a knowledge gap when it comes to the relationship between information providers and individual farmers including important factors like trust and communication. Liu et al (2018) created a conceptual model to distinguish the macro-scale agricultural influences and the micro-scale, farm-level influences (Appendix 3.3) with information, trust, and incentives in between the two levels concluding that BMP adoption on the farm is less likely to occur if these mediating factors are omitted. This paper explores this knowledge gap by using social factors to theoretically improve the communication, relationship, and trust between the macro-scale and micro-scale of agriculture. The social factors that affect the adoption of BMPs in agriculture can be utilized to encourage a new way of providing information to farmers and to policy makers.

The purpose of this scoping review is to synthesize the recent research on the adoption of BMPs in agriculture and find what social factors influence that decision. Unlike, Baumgart-Getz et al (2012), this review includes more than just social factors because the complexity of the decision to implement a BMP can simultaneously be influenced by economic factors, farm management factors, and government factors. The focus is social factors, but the other factors cannot be ignored. In this paper, common barriers and enablers of BMP adoption were identified and categorized. It includes articles from high-income areas like Canada, the United States,

Australia, New Zealand, and European countries so that systems and approaches with similar adoption obstacles to Canada, can be assessed. The studies chosen, focus on the adoption of agricultural BMPs that are intended to mitigate an environmental issue.

Research Question:

- **What are the social factors that affect the adoption of BMPs in agriculture?**

2. Methods

A search string was developed to find relevant peer-reviewed articles about the factors that influence the adoption of BMPs in agriculture using two databases: Scopus and Web of Science.

2.1 Search String

For Web of Science:
TS=((socioeconomic* OR "socio-economic*" OR livelihood OR social* OR psycho*) NEAR/3 (adopt* OR decision OR behav* OR adapt* OR attitude) AND (innovat* OR technolog* OR "best management practice*" OR bmp) AND(influence OR barrier OR enabler OR facilitator OR challenge OR solution OR impact) AND (sustainable* OR sustainability OR conservation OR environment) AND (farm* OR agri* OR agro*))

For Scopus:
TITLE-ABS-KEY ((socioeconomic* OR "socio-economic*" OR livelihood OR social* OR psycho*) AND (adopt* OR decision OR behav* OR adapt* OR attitude) AND (innovat* OR technolog* OR "best management practice*" OR bmp) AND (influence OR barrier OR enabler OR facilitator OR challenge OR solution) AND (sustainable* OR sustainability OR conservation) AND (farmer))

The search strings resulted in 820 articles. Duplicates were removed using Mendeley reference manager leaving 694 titles and abstracts to be screened. A program for managing review material, Covidence (free trial limited to a maximum of 500 articles able to be imported) was

used to organize the articles as I determined whether they were relevant to the study or not, by screening each articles' title and abstract to the conditions outlined in the document "Title and Abstract Screening" (Appendix 2.1). This left 194 articles in Mendeley for title and abstract screening without the help of Covidence, which consisted of reading the title and abstract only and searching for evidence that the study was related to agriculture, adoption factors, and performed in a high-income country. I performed this task using the same "Title and Abstract Screening" document from above.

From 694 articles, only 66 continued to the next step of full text screening based on the criteria in the document "Full Text Screening Code Guide" (Appendix 2.2). This document was developed to help define the information to be extracted. Full text screening involved the 66 articles being read fully and selected based on the following inclusion criteria:

- studies of farmers,
- a BMP that mitigates an environmental issue,
- the social factors involved in the farmer's decision-making for adoption,
- if the study took place in a high-income country.

While reading the article, data was extracted in an excel spreadsheet with the following categories: bibliographic information, farmer information, sustainable agriculture, adoption information, micro vs. macro, and knowledge gaps with each category containing many columns.

In the end, 17 articles contained the information sought after. The data collected from these articles were qualitatively analyzed using Excel to organize and group together similar findings based on the topics that could be factors based on preliminary readings of keystone papers. As part of the qualitative analysis process, I categorized the extracted data based on the

adoption information including factors, barriers, and enablers and the data were input into a table. The barriers and enablers were listed into many subcategories (Figure 2.1) and were then categorized into four broad themes of factors: Economic, Social, Government, and Farm Management. These themes were deductively influenced by Ranjan et al (2019) who included these same themes in their research as well as more. The extra themes mentioned in Ranjan et al (2019) are also discussed in this study in Farmer characteristics and Environmental Issues and BMPs or in the micro vs. macro discussion on communication, relationships, and trust. Together, all these pieces affect a farmer's decision to adopt, but the Social factors are our primary focus and go hand-in-hand with Economic, Government, and Farm Management factors.

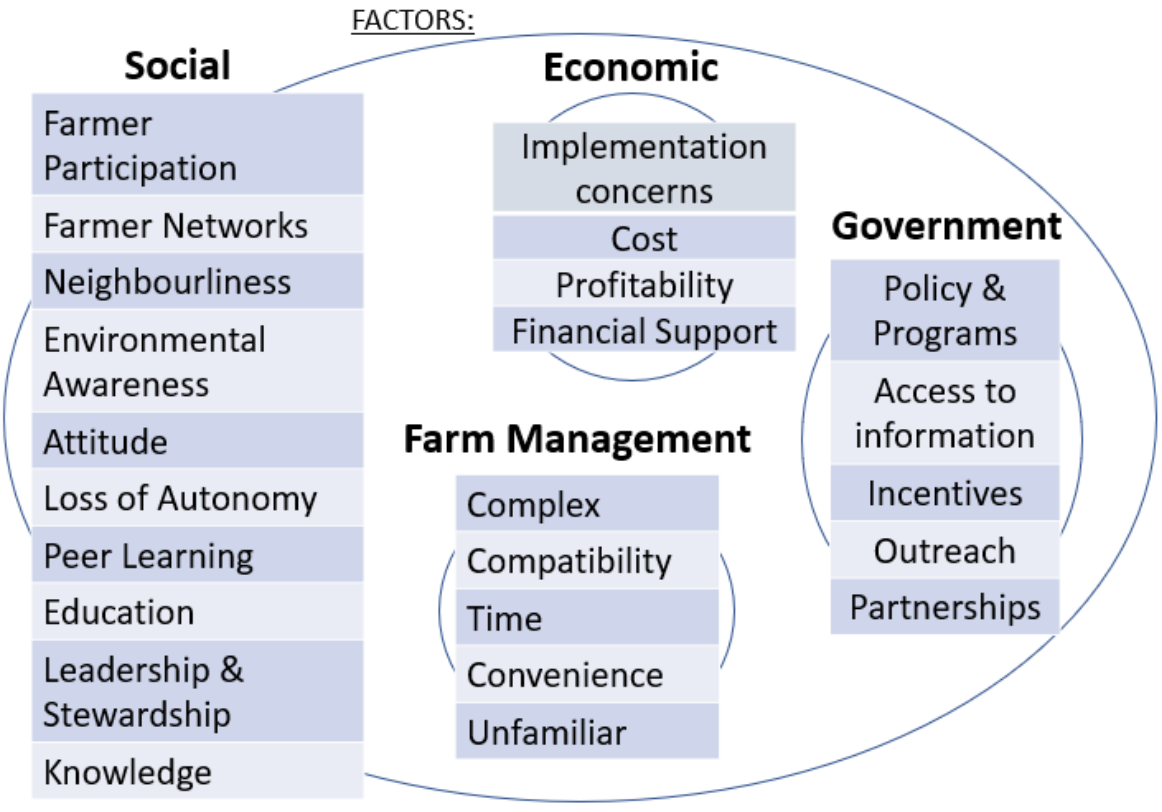

Figure 2.1 Factors included in review. The subcategories of factors acting as enablers or barriers to adoption of BMPs in agriculture as well as the four themes they are categorized into. Social factors work together with other factors to become a barrier or enabler to adoption.

3. Results and Discussion

Factors that influence the adoption of BMPs in agriculture.

The environmental issue and the BMPs investigated in each study were identified to ensure the articles reviewed focused on the adoption of BMPs to address environmental concerns. In the 17 studies that fit the criteria (Appendix 3.1), they encompass 7238 farmers in 14 studies being surveyed or interviewed about adoption factors, and three articles that are reviews that include 126 studies. Both qualitative and quantitative analyses were used in these studies as well as various modeling methods such as Rodriguez-Entrena et al (2014) who used a statistical approach called Structural Equation Modeling (SEM), Lioutas & Charatsari (2018) who used the statistical Pierson's Correlation to find relationships, and Rochecouste et al (2015) who used a qualitative modeling called Causal Loop Diagrams (CLD) to find causal relationships between factors (Appendix 3.2).

3.1 Farm Characteristics

Of the 17 studies included in this analysis, all were conducted in high-income countries as specified in the search string (Figure 3.1). Most of the studies that formed the dataset for this analysis included farms that produced more than one type of crop for a livelihood or included various types of farms in their study (Figure 3.2).

In Daxini et al (2019), around 6% of the survey responders stated they operated a tillage farm. Tillage is not defined in the article but usually refers to land that is cleared in the preparation for crops. It is not a product of the farm, but it was listed in the article as a type of farm, so it is being included as such in this study. Daxini et al (2019) research was conducted in Ireland, so it is possible tillage means something different there than it does in North America.

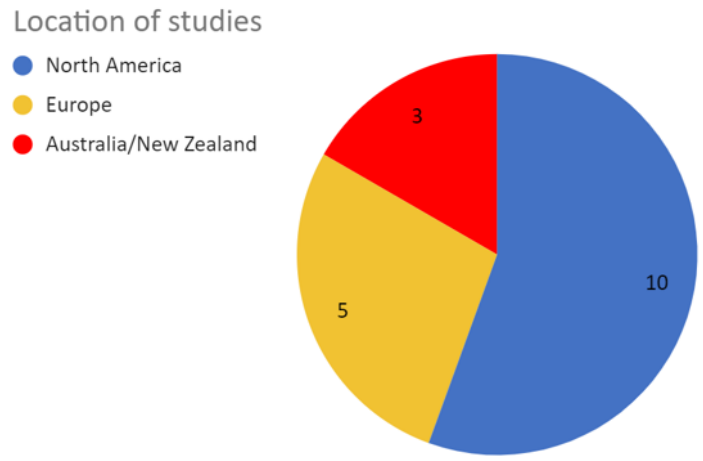

Figure 3.1 Location of studies. The continents where the 17 studies were conducted. Take note that one study (Niles et al 2019) took place in both Europe and North America.

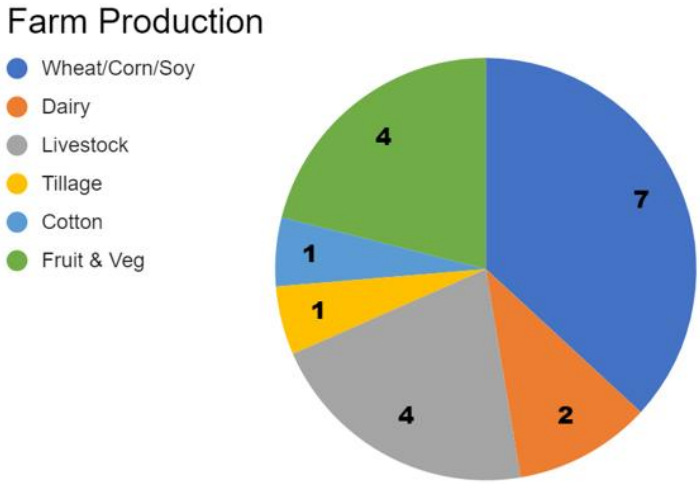

Figure 3.2 Farm production. The numbers in the pie chart represent the type of farm operated by the respondents in the studies. Many farms produced more than one product, or the studies included various types of farms which is why there are more farm production types than the 17 studies involved.

Ownership, defined as whether the farmer owns the land and does not rent it, was only mentioned six times out of the 17 studies. When farm ownership was mentioned, the study often included both landowners and renters. Farm size was mentioned in 11 of the studies and pertained to the size of the farm in acreage. Depending on the type of farm, large and small were

defined differently, but all 11 studies included large and small farms as well as various sizes in between.

The experience of the farmer (herein called ‘farmer experience’) was only mentioned in seven articles. This is a variable of interest because the amount of experience a farmer has could be related to the farmer’s knowledge of BMPs, or if the farmer has a leadership role in the farming community, or how willing the farmer is to change their practices. Small et al (2016) surveyed farmers with an average of 25 years of experience, Daxini et al (2019) surveyed farmers with an average of 36 years of experience, and Lioutas & Charatsari (2018) only surveyed young farmers with the mean age being 31 years old. These three studies only recorded these figures for socio-economic purpose and not to analyze it with the factors.

Three of the studies did not mention any years of experience or age of participants but all farmers surveyed (Rochecouste et al 2015, Zimmerman et al 2019) were currently in multigenerational farming families or most farmers surveyed (Juntunen et al 2019) grew up in farming families leading to the assumption the farmers had a significant amount of farm experience. However, the only conclusion about farmer experience and its influence on adoption of BMPs is by Baumgart-Getz et al (2012) who investigated the results of 45 studies and statistically determined that the relationship between farmer experience and the adoption of BMPs is not significant.

3.2 Environmental Issues and BMPs

Environmental issues were categorized as biodiversity loss, climate change effects, water quality concerns, and soil quality and erosion as per Agriculture Canada’s environmental issues related to agriculture (Agriculture and Agri-Food Canada, 2021b). Six studies named their main environmental concern to be sustainability or included more than one of the above (Appendix

3.1). Eight studies looked at a variety of BMPs that would help mitigate their environmental issue(s), while five studies focused on a specific BMP such as cover crops or field edge habitat. Four studies looked specifically at agriculture plans or strategies that would implement practices better for the environment which differs from the aforementioned BMPs because these are more than physical actions, they are long-term, thought out plans, and usually include more than one BMP to be implemented (Appendix 3.1) such as Manure Management Strategies (MMS) studied by Niles et al (2019) and Nutrient Management Plans studied by Daxini et al (2019).

3.3 FACTORS

The factors found in my dataset that affect whether BMPs are adopted or not are categorized into four main groups: Farm Management, Economic, Government, and Social factors.

3.4 Farm Management

Farm management includes any operational factors that pertain to how the farm runs. These factors can be altered to reduce a farm's environmental impact (Table 3.1) such as investing more time to implement a BMP to reduce the amount of nutrients in runoff or being inconvenienced by BMPs that may take more work than conventional methods but increase the biodiversity of native fauna and flora. In contrast, farm characteristics are the fundamental information about the farm such as size, what is being grown or produced, soil type, slope of the land, or surrounding watershed conditions. The farm characteristics could potentially change as well but it would be a large, fundamental change that would affect many other characteristics about the farm.

An example of farm management factors is compatibility of the BMP with the farm. If the BMP being considered for adoption is to stabilize slopes by planting a riparian buffer but the

farm characteristically is flat and not experiencing erosion, this results in an incompatibility between the BMP and the farm because the BMP is not beneficial nor detrimental for the farm or the environment. A riparian buffer could still be planted if desired, and it may provide other mitigation to other problems, but it is not being implemented specifically to help fix soil erosion on slopes because the farm is lacking slopes and soil erosion. Incompatibility between the equipment or infrastructure of the farm versus what is required for the implementation of a BMP will hinder adoption (Ranjan et al 2019). The farmer knows their land characteristics so if they perceive the BMP will not be successful due to their soil type, crop, field size, etc. then there is no motivation to implement the BMP (Zhang et al 2016). The farmer's knowledge of their land and practices is information that would be useful for policy makers and information providers when creating BMPs, programs, and incentives to improve their relevancy and ability to fulfill the farmer's needs. Compatibility issues prove that not all BMPs will work on all farms.

A farmer who is unfamiliar with a BMP, cannot implement it. Rochecouste et al (2015) concluded that a BMP that is not already widely used and that is not practiced by other farmers in a community, will be slow to be adopted. The farmer must have access to information about the BMP to decide whether to implement it or not. The information providers have knowledge that they want to give to farmers and effective communication is key to delivery.

Farm management barriers can include convenience and time. Farmers may view the BMP as not worth the time or effort required to implement the practice, which pertains to how the farm is being managed. Lioutas and Charatsari (2018) found that the perception of the BMP being inconvenient, as well as the perception of the BMP having a negative economic impact, is a stronger factor against adoption than the positive influence of a farmer group towards adoption.

The greatest barrier to adopting a BMP under farm management is complexity of the BMP and its implementation. Rochecouste et al (2015) concludes that complex practices will result in less adoption either due to the farmer lacking confidence in their ability to implement such a complex practice successfully or if the BMP may require asking for help. To someone who is not a farmer, adding a wildlife buffer, planting a cover crops field, or rotating livestock might seem easy and straightforward, but farmers know these practices are more complex and include being able to go around buffer areas with equipment, fencing off cover crops to livestock, or the extra labour and planning of rotating cattle (Zimmerman et al 2019). Farmers must think of all these extra hidden tasks, and possible costs that come along with implementing a new practice because it is not as simple as just adopting a BMP and this is their farm reality. Rochecouste et al (2015) and Baumgart-Getz et al (2012) observed that it is not just one factor that ultimately influences the adoption of BMPs in agriculture, but a complex mixture of many factors.

Table 3.1 *Studies including Farm Management Factors as Barriers or Enablers*

Factor	**Description**	**Barrier**	**Enabler**	**Studies including this factor**
Complex	Complexity of the process for implementing or actioning the BMP	3	0	Baumgart-Getz et al (2012); Zimmerman et al (2019); Rochecouste et al (2015)
Compatibility	Fit of the BMP and the farm to work together	2	0	Ranjan et al (2019); Zhang et al (2016);
Time	Commitment of time to implement the BMP	3	0	Ranjan et al (2019); Garbach & Long (2017); Zhang et al (2016);
Convenience	Ease of implementing the BMP	2	0	Lioutas & Charatsari (2018); Zhang et al (2017);
Unfamiliar	Farmer's knowledge or access to information about BMP	1	0	Rochecouste et al (2015);

3.5 Economic Factors

The cost of implementing a BMP is by far the largest economic barrier for the adoption of BMPs (Table 3.2) as found in seven studies. Boz (2018) mentions how the inability to purchase irrigation equipment, organic fertilizers, or certifications are a barrier for low-income farmers or for farmers who rent land and cannot secure a bank loan since they do not own land. Ranjan et al (2019) had focus group participants who believed farming on rented land, or with short-term contracts, offered little incentive for investing in implementing BMPs. Niles et al (2019) found cost to be a barrier for implementing expensive manure management strategies among dairy farmers. Additionally, Barreiro-Hurle et al (2010) found that the transition costs of changing to a new practice is a barrier to BMP adoption. These studies concur with Rochecouste et al (2015) findings that the higher the initial cost of implementation for the BMP, the slower the practice is adopted, especially if a result takes years to see instead of a season.

Related to cost of implementation is the implementation concerns and perceived risk of failure of the BMP mentioned by Mishra et al (2018). The farmer's worries could be eased by learning more about the new practice or by outreach from a local farming group or other farmers who can introduce the BMP and address questions. This example weaves social factors into the adoption of BMPs by mitigating an economic barrier with social networks, outreach, and neighbourliness and it highlights how farmer decision making is influenced by various types of factors.

Just as cost is a barrier, profitability is an enabler to the adoption of BMPs in agriculture. In Garbach & Long (2017) study, 25% of BMP adopters credited profits to the benefits of field edge planting such as the increase in native bees who pollinate and natural predators who control pest populations. According to a study by Rodriguez-Entrena et al (2014) of olive growers in

Spain. They expected economic factors to be a major reason for the adoption of cover crops and the results showed a positive relationship between large farms and profitability as an enabler for the adoption of soil conservation practices. However, for smaller olive growing operations, profitability was an enabler, but the strongest influence was whether the farmer belonged to a social network. This calls attention to how upfront costs can be a barrier for smaller farms who are unable to wait for profits or other benefits of adoption and how a farmer's network can help mitigate some economic barriers. Boz (2018) showed that providing financial support from agri-environmental government programs that promote the use of BMPs was an enabler to the adoption of BMPs. Having the funds to test a BMP and adapt it to the specific farm before fully committing would be beneficial to adoption of the practice without the risk of losing money. Full commitment could include purchasing equipment, time consumption, or hiring labourers.

Table 3.2 *Studies including Economic Factors as Barriers or Enablers*

Factor	**Description**	**Barrier**	**Enabler**	**Studies including this factor**
Implementation concerns and perceived risk of failure	Worry and hesitance to adoption due to the possibility of the BMP failing or implementation being unsuccessful.	1	0	Mishra et al (2018);
Cost	Any financial obligations related to the BMP such as upfront equipment costs, or labour pay throughout the BMP implementation.	7	0	Niles et al (2019); Boz (2018); Ranjan et al (2019); Zimmerman et al (2019); Barreiro-Hurle et al (2010); Garbach & Long (2017); Rochecouste et al (2015);
Financial support	Costs being covered for the implementation of a BMP or money being provided in the case of lost profits or as an incentive to adopt a BMP.	0	1	Boz (2018);
Profitability	Receiving more money for a product than it cost to produce.	0	2	Rodriguez-Entrena et al (2014); Zhang et al (2016)

3.6 Government Factors

Certain government agricultural policies and programs are perceived as barriers in the adoption of BMPs because policies are perceived as irrelevant and program registration can be too complicated. However, some government policies and programs that promote access to information, government incentives, farmer outreach, and community partnerships are viewed as enablers that help the adoption of BMPs (Table 3.3). The type of government policy or program may be viewed as a barrier. For example, Niles et al (2019) and Ranjan et al (2019) found that government policies were barriers when they were rigid and unable to conform because just like farms differ, so do farmers as some are early adopters and others take longer or will continue in their regular practices. As well, some farmers feel uncertain about the regulations or that they do not pertain to their specific farm. If there are any costs associated with implementing the BMP, Niles et al (2019) found that participation would plummet and that farmers were much less likely to participate in a government incentive program a second time. In the case of a government incentive program that grants funds to purchase expensive anaerobic digester equipment for a manure management strategy (Niles et al 2019), it makes sense that once the farmer owns the equipment, they probably do not feel they need the government's assistance anymore and will not participate in a second incentive program.

Farmers perceive government programs with complex registration processes as a barrier leaving the farmer with negative experiences from the administrative process and creating reluctance to participate again (Niles et al 2019 & Ranjan et al 2019). A potential solution would be to have local farming organizations assist farmers one-on-one with any complicated application registration forms to ease the process, and answer questions while mitigating barriers to the adoption of BMPs. Interviewees in Zimmerman's et al (2019) study complained about

government incentive programs taking a long time to come into effect, and the registration process being a huge hassle as well, similar to what was noted above.

Interviewees in Boz (2018) focus groups believe government agricultural policies and programs are influential in the adoption of BMPs, and that they must focus on sustainability. However, the policies and programs in place can be inconsistent like providing an incentive for native grasses that are not alfalfa since it requires too much water but in a different policy, providing an incentive to grow livestock crops like alfalfa. The program may also be incomplete such as having the farmer install irrigation equipment but not providing training to the farmer about how use it. The answer should not be to scrap incentive programs but to work with farmers to improve them so that they are accessible and meeting farmer's needs.

Ticehurst et al (2011) found government programs to be an enabler to adopting a BMP. This study took place in Australia and the BMP to adopt was fencing native bushland to protect it by preventing livestock access to it. Fencing is a very expensive endeavor so joining a government program that provides financial assistance and information is a key enabling factor for the adoption of this BMP. Ticehurst found that 99% of adopters were also part of a local group or participated in a local course about the subject either of which provides assistance for enrolment in the government program that is providing the funding. This study highlights the importance of government programs that help with enrolment for government incentives which breaks down the main barrier of cost and offer access to support that may be a beneficial tool to encourage the adoption of BMPs. Having positive government programs like this could help eliminate government policies being perceived as barriers by farmers, by opening up communication between farmers and policy makers so policy being created could be more flexible and relatable to a farm's reality.

Partnerships that include agricultural, conservation non-profits, and government bodies enable the adoption of BMPs in agriculture perhaps because of the communication and knowledge being exchanged (Zimmerman et al 2019). A group with people of different backgrounds would provide various ideas and possible solutions to barriers of adoption of BMPs as well as more transparency on policies being created, or what farmers need in programming and incentives. Therefore, access to information through government programs, policy, education, or social groups is an enabler to the adoption of BMPs in agriculture too (Mishra et al 2018). It reduces other perceived barriers because having a greater knowledge of the practice to be implemented, the how, where, why, and when, reduces uncertainty and risk. Understandably, farmer outreach is also an enabler to adoption since engaging with someone knowledgeable about the BMP would allow for all questions a farmer may have about the practice to be answered, making implementation easier and more likely.

Table 3.3 *Studies including Government Factors as Barriers or Enablers*

Factor	**Description**	**Barrier**	**Enabler**	**Studies including this factor**
Government policy and programs	Policy: A rule or principle to help influence decision-making, hopefully with results that would enhance the community. Program: Created by policy to help in the distribution of policy and provide public service.	3	2	Niles (2019); Zimmerman et al (2019); Ranjan et al (2019); Ticehurst (2011); Boz (2018);
Access to information	Exposure to information, policy, or knowledge of a BMP and ability to ask questions and receive answers to gain knowledge.	0	1	Mishra et al (2018);
Incentives	A positive motivation or bonus to encourage a decision or action.	0	1	Zimmerman et al (2019);
Farmer outreach	To connect with farmers to inform about policy, programs, incentives, and encourage communication.	0	1	Mishra et al (2018);
Partnerships	An association of groups and individuals from various sectors, communicating and sharing ideas.	0	2	Zimmerman et al (2019); Zhang et al (2016)

3.7 Social Factors

Farmer networks are the leading factor enabling the adoption of BMPs in agriculture as they provide the opportunity for farmers to learn about various BMPs from other farmers with experience implementing the practices. The term farmer or social network can refer to farm associations, community organizations, watershed councils, conservation authorities, or any local organization where community members can interact, and communication and information can be transferred. Following networks as enablers to adoption of BMPs are environmental awareness, education, and leadership/stewardship (Table 3.4).

Having a social network leads to conversations about BMPs, the pros and cons of adoption, and perhaps the persuasion, resources, and help to implement the practice from your neighbours and friends. Niles et al (2019) found that social networks influenced the adoption of manure management strategies for dairy farmers because they had other dairy farmers to exchange manure with and it spawned respect between the farmers. Unsurprisingly, social networks increase the communication among farmers. Farmer interaction and networking inevitably leads to more access to information, education, and motivation for adoption of BMPs in agriculture (Mishra et al 2018). As mentioned above, Rodriguez-Entrena et al (2014) found the main enabler for adoption of soil conservation practices in Spain for small area olive growers was social networks. Having neighbours and friends to help implement a BMP knocks down many barriers to adoption.

Manson et al (2016) takes a deep dive into the social networks and relationships of dairy farmers and found that successful farmers usually depend on their farmer networks for information about their animals and their pastures but that this social interaction can develop a sense of what a healthy environment and farm is. The network can also provide help and

equipment loans from your neighbours to implement rotational grazing which mitigates barriers related to cost.

Similarly, social factors like farmer participation, leadership/stewardship, and neighbourliness can coincide with social networks. If farmers are included in the plans for the implementation of BMPs in agriculture, adoption is more likely to occur (Barreiro-Hurle et al 2010). This would require communication between farmers, conservation organizations, and government agencies. Some farmers would take on leadership roles in these organizations and partnerships and share information with others (Ranjan et al 2019) which fosters trust in the community.

Attitude and environmental awareness are not significant factors but as Baumgart-Getz et al (2012) conclude, all social factors naturally work together to significantly impact the adoption of BMPs. The only social factor considered a barrier was the perceived loss of autonomy. Zimmerman et al (2019) interviewed farmers who feared adoption of BMPs due to government regulations or government programs that would take away their decision-making freedoms. It is the farmers' land and ultimately it is their choice whether to adopt a BMP or not and these farmers did not want to be told what to do.

Table 3.4 *Studies including Social/Psychological Factors as Barriers or Enablers*

Factor	**Description**	**Barrier**	**Enabler**	**Studies including this factor**
Farmer participation	Farmer included in policymaking, programming, or community initiatives.	0	1	Barreiro-Hurle et al (2010);
Farmer Networks	A social group of farmers, neighbours, and community members who gather to discuss local issues.	0	4	Niles et al (2019); Mishra et al (2018); Rodriguez-Entrena et al (2014); Manson et al (2016);

Neighbourliness	People who live nearby and are friendly and thoughtful towards each other.	0	1	Niles et al (2019);
Environmental Awareness	Aware of environmental issues.	0	2	Baumgart-Getz et al (2012); Small (2016);
Attitude	Opinions and perceptions that are reflected in one's actions.	0	1	Baumgart-Getz et al (2012);
Loss of Autonomy	Not having control over one's actions.	1	0	Zimmerman et al (2019);
Peer Learning	Learning from fellow farmers or community members.	0	1	Manson et al (2016);
Education	Knowledge learnt from experience and/or institutions.	0	2	Mishra et al (2018); Rochecouste et al (2015);
Leadership/Stewardship	Being influential in one's community and leading others in decision-making.	0	2	Ranjan et al (2019); Juntunen et al (2019);
Knowledge	The understanding of information and skills gained by experience and/or education.	0	1	Mishra et al (2018);

3.8 Micro and Macro Factors in Agriculture

Macro factors are larger scale factors that influence agricultural practices such as climate, global location, watershed conditions, government policies, market viability, and the risks associated with the product being produced. These macro factors influence the adoption of BMPs in agriculture, but adoption of agricultural BMPs often occur at the micro/farm scale level (Liu et al 2018). Adapted from Liu et al (2018)'s conceptual framework of BMP adoption (Appendix 3.3) an updated figure was created to introduce a loop strategy of adoption as opposed to a top-down approach (Figure 3.3). Liu et al (2018)'s framework distinguishes between the macro scale of agriculture (watershed, regional, or national) which are factors that are imposed on the farmer such as policies, incentives, programs, and BMP recommendations, from the micro scale of

farmers who would turn the ideas, words, strategies into reality. In between the two scales are information tailoring and incentive targeting, which Liu et al (2018) admit makes a top-down concept challenging since trust is a by-product required to shift the conceptual BMPs, policy, programs, or recommendations to the micro/farm scale level.

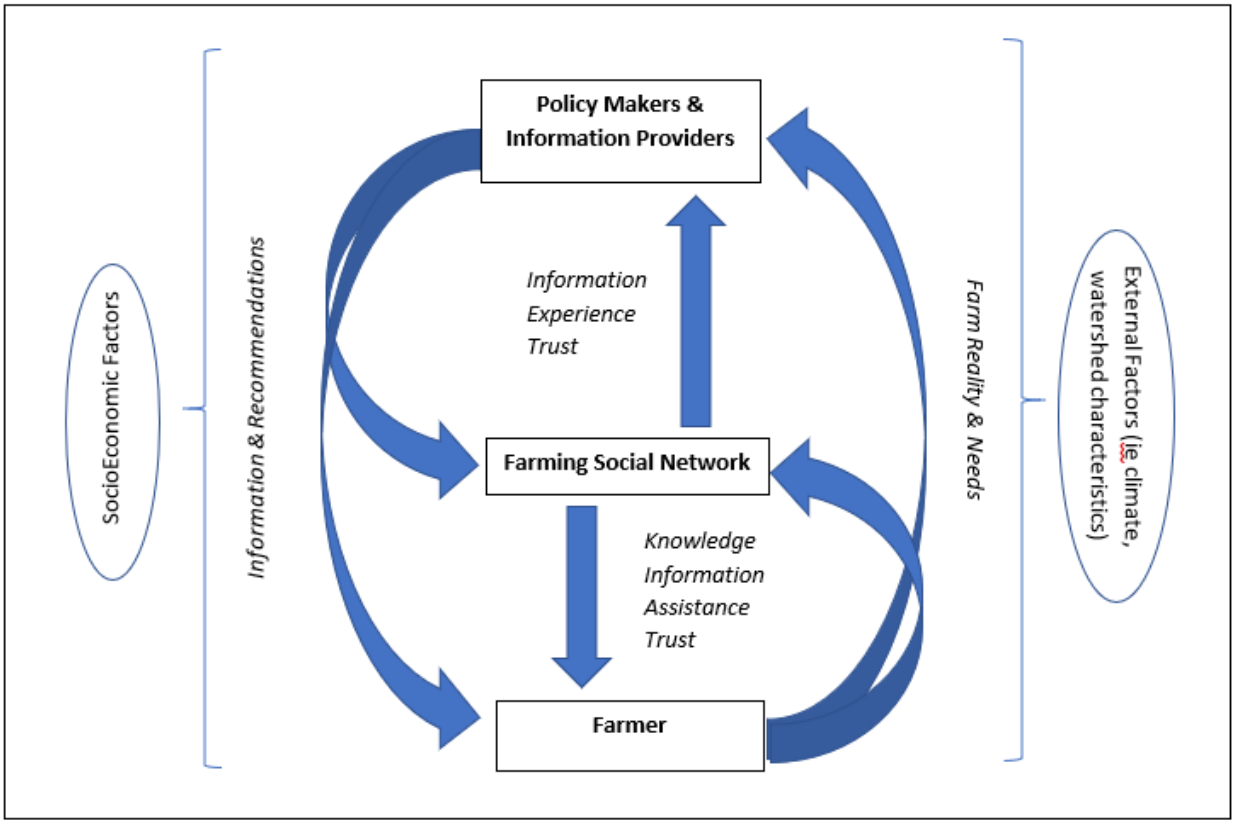

Figure 3.3 Loop communication conceptual BMP adoption model. A loop model of communication that would transfer information & recommendations down from policy makers to the farmers and transfer the farm reality & needs up from the farmer to the policy makers. Farmer networks in the middle help the transfer and can mitigate other barriers and provide enablers to adoption.

The updated concept (Figure 3.3) is a loop to represent the feedback and iterative movement of communication, which showcase the relationships with the benefits being offered. Lioutas and Charatsari (2018) agree that the top-down, and linear models used in the past are now outdated. In this updated concept, the policy makers and information providers are receiving

information from farmers about what the farm reality is and what they need to be able to succeed from the unified voices of the farming community. Information like this can then be used to craft effective BMPs that can be more readily implemented or create programs and incentives that will be used by farmers to aid adoption of BMPs. Including various voices from across different sectors will add new ideas and flexibility to this model as well as build an alliance and stronger relationships (Manson et al 2016).

The social network and relationships are at the centre of this figure because they are trusted by farmers and encourage the adoption of BMPs (Ranjan et al 2019). Farmers are more likely to trust other farmers and local farming groups and less likely to trust information sources less familiar like government agencies or academic institutions (Ranjan et al 2019). Having a mediating, local group between the macro level and the micro level, that is made up of neighbours and community members that are already known and trusted, could help encourage communication and foster a working partnership with people from other sectors. A network also serves the purpose of bringing together the community to have discussions on local matters and organizing what information is important for relaying back to policy makers and information providers on the macro-level.

Government agencies, being in the macro scale of agriculture, can be distrusted by farmers especially if there is a lack of effective communication. In Zimmerman's et al (2019) study, 60% of interviewees did not trust the government and would not participate in government programs believing it all to be a hassle, ordeal, and a waste of money. This equates to irrelevant policy, unimplemented BMPs, and a loss of knowledge since it is not making its way down to the micro level.

Socioeconomic factors such as cost, environmental awareness, or attitude to name a few, and external factors such as climate, the watershed characteristics, or geographic location, will affect all levels of agriculture from the macro to the micro level, and so these factors are placed on the outside of the loop figure (Figure 3.3), but remaining in the picture. Incorporating a more circular model of communication will strengthen the relationships among the macro and micro levels of agriculture as well as create trust so that action to address environmental issues can occur.

4. Conclusion

Complexity is evident in each of the 17 articles reviewed, as it is never a single factor that is the barrier or enabler for adoption of a BMP in agriculture but rather many factors together. The social factors emerged as an important theme for the enabling of adoption and it makes sense because these factors can mitigate barriers. Through farmer networks stems education, peer learning, farmer participation, leadership/stewardship, neighbourliness, and environmental awareness. These factors can mitigate the largest barrier of cost, but also implementation concerns, complexity, time, convenience, and assist with government programs.

Having farming networks mediate between farmers and policy makers and information providers allows a loop communication model to function: relaying government policy, programs, incentives, and BMPs to travel to the individual farmers, and allowing the farmer's needs and farm reality to travel back to the policy makers and information providers. In previous linear communication models, information about BMPs was either failing to be communicated effectively, or there was a lack of trust between the farmer and the information provider resulting in slow adoption of BMPs. Further research in communication styles, relationships, and trust

between information providers and farmers should be considered to help increase the adoption rate of BMPs in agriculture. Climate change, water quality, soil quality and loss of biodiversity are imminent concerns and agricultural practices must become more sustainable to address these environmental issues.

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6. Appendix

2.1 Title and Abstract Screening

Social factors to farmers' adoption Scoping Review - Title & Abstract Screening Questions

Research Question: What are the social factors affecting the adoption of sustainable agriculture practices for farmers?

Focus on: "Farmer's awareness and interest in Sustainable agriculture", "Information and recommendations from Information providers" and "information tailoring and trust between farms and policy makers/researchers (macro and micro)".

NOTES:

- If you answer "NO" to any question, the citation will be **EXCLUDE Irrelevant.**
- Once you decide NO to any question, move on to the next citation and DO NOT answer the subsequent questions.
- If "YES" to **ALL** questions (without doubt), then **INCLUDE on title & abstract.**
- If there are any questions or you need more information about criteria, the study is to be included **(INCLUDE for second opinion)**.
- If the abstract is missing, you can search for the paper online and copy and paste the abstract into EPPI and then screen. In general, if an abstract is missing and cannot be found (i.e., try to find it first on Google, Google Scholar, etc.), and title alone is not enough to determine inclusion/exclusion, **INCLUDE for second opinion**, and add a note by clicking the "info" button next to Include.

Question 1: Is this study about farms, farmers, or agriculture and adoption of an agricultural practice?	
Responses	• **Yes (Include)** • **No (Exclude)** • **Unclear (Include Second Opinion)**

Notes	• Include if mentioned terms such as
	  • farm
	  • farmer
	  • agri*
	  • agro*
	  AND
	  • adopt*
	  • adapt*
	  • decision
	  • behav*
	  • attitude

Question 2: Is this study about the social/psychological factors of adoption?	
Responses	• **Yes (Include)** • **No (Exclude)** • **Unclear (Include Second Opinion)**

Notes	• Include if **directly** studying the social/psychological factors.
	  • E.g., interviews, user feedback, indicators, or measures
	• Include if **indirectly** studying social/psychological factors.
	  • E.g., study evaluates other factors of adoption (economical/cultural/law)
	  • E.g., studying the wider benefits of agricultural innovation (like sustainable/conservational agricultural practices, best management practices, promoting biodiversity, etc.)
	• Exclude if the paper's focus is ONLY on the agricultural practice and not on any social or adoption factors.

Question 3: Is this study relevant to a developed country?	
Responses	• **Yes (Include)** • **No (Exclude)** • **Unclear**
Notes	• Include if **directly** discusses farmers' adoption factors in Canada, US, Europe, Australia. • Include if **indirectly** discussing farmers' adoption worldwide/ in general/ not specified location. • Include if **directly** discusses farmers' social/psychological adoption factors (no matter the location) • Exclude if the paper focuses on a developing country or an area where the agricultural practices and adoption factors would be quite different from Canada and Europe and the focus is mostly on agricultural practice.

Question 4: Does this study involve sustainable agriculture?	
Responses	• **Yes (Include)** • **No (Exclude)** • **Unclear**

Notes	• Include if mentioned terms such as
	  • Conservation agriculture
	  • Sustainable agriculture
	  • Soil conservation
	  • Water conservation
	  • Biodiversity
	  • Best management practices
	  • Agroecology
	  • Climate Change

2.2 Full Text Data Screening Code Sheet

Full Text Data Screening Code Sheet

The following information will be extracted and presented in a summary table.

Template for the below data coding sheet:

Section for Data Extraction

1. The Type of Data Extracted
    - *Any further explanation on the data extracted.*
    - Option 1 (if applicable)
    - Option 2 (if applicable), etc.

Bibliographic Information

1. Full Reference
2. DOI
3. Year Published
4. Title of Article/Chapter
5. Title (Journal, Book, Report, Thesis)
6. Type of Publication
    - Peer-Reviewed Article
    - PhD Dissertation
    - Master's Thesis
    - Report (Government, NGO, Consultant)
    - Proceedings/Conference Paper
    - Workshop Summary
    - White Paper
    - Book
    - Other
7. Author affiliation

Agriculture Data

7. Country of study
8. Prov/State of study
9. Urban/Rural
10. How many farms are in the study?
11. Ownership (if mentioned)
    - Rent
    - Own
    - Other
12. Sector (if mentioned)
    - Market Vegetables

    - Livestock
    - Cash Crops
    - Other
    - Multiple
13. Farm size (if mentioned)
14. Experience
    - *What kind of prior agricultural experience does the farmer have? (If mentioned)*
15. Agricultural practices being studied
    - *This includes any BMP or sustainable/conservational practice.*
16. Environmental Issue
    - Biodiversity
    - Water Quality/Retention
    - Soil Retention
    - Climate Change
    - Other
16. Is it a technological innovation or practical innovation?
    - *Tech would involve equipment/machinery and practical would involve physical labour/actually doing a practice.*
    - Technology
    - Both
    - Practical
    - Neither
17. Is it community knowledge or a new introduction?
    - *Only if mentioned.*
    - Community knowledge would include if neighbours were using the practice and it is established in the area; New introduction would assume the practice is innovative and unheard of before the study.
    - Community Knowledge
    - New Introduction
    - Both
18. Farmer's knowledge/awareness of sustainable agriculture
    - *Only if mentioned.*

Adoption Factors

19. What type of factors are being studied?
    - Social
    - Economic
    - Environmental
    - Other
20. What are the specific social or psychological factors?
21. What are the methods of how they are being measured?
22. Barriers
    - Any negative results that impede the adoption of a BMP practice.
23. Enablers
    - Any positive results that improve the adoption of a BMP practice.

24. Incentives
    - Any positive reinforcement provided to the farmer for adopting a BMP practice.

Micro and Macro Relationship (macro=policy makers/researchers; micro=farmers)

25. How are the information providers providing their information?
    - Formal education through a course/class/program at a local educational facility.
    - Researchers are providing information via pamphlets/workshops/outreach, etc.
    - Policies are being put in place to encourage the use of BMP.
    - Other
26. Are farmers using the information provided by policymakers/researchers?
    - Yes
    - No
27. Does the information provided meet the farmers' needs?
    - *Only if mentioned.*
    - Did the study provide how the farmers feel about the information provided?
28. Is trust mentioned in the study?
29. What is the relationship between the farmer and the information provider?
    - *Only if it is mentioned.*
    - For example, is it a collaboration? Outreach organization? No relationship?
30. What is the information source between the farmers and researchers/policy makers?
    - *Only if it is mentioned.*

Knowledge gaps

31. Are knowledge gaps discussed?
    - Yes
    - No
32. If yes, what knowledge gaps are discussed?
33. If yes, what future considerations on knowledge gaps are discussed?

3.1 The Environmental Issues and BMPs being studied.

Reference study	Environmental Issue	BMP being studied
Niles 2019	Sustainability	Manure Management Strategies (MMS)
Baumgart-Getz et al 2012	n/a	Various
Boz 2018	Sustainability	Agri-environmental programs
Ranjan et al 2019	Water Quality	Conservation practices and programs
Mishra et al 2018	Soil Quality, Water Quality, and Sustainability	31 various sustainable agriculture practices (SAPs)
Daxini et al 2019	Soil Quality	Nutrient Management Plan
Zimmerman et al 2019	Soil Quality, Water Quality, and Biodiversity	BMPs (various)
Zhang et al 2016	Water Quality	Nutrient runoff
Garbach & Long 2017	Biodiversity	Field Edge Habitat
Barreiro-Hurle et al 2010	Sustainability	Sustainable Development Goals (SDGs)
Small 2016	Water Quality	6 BMPs
Ticehurst 2011	Biodiversity	Fencing of Bushland
Rodriguez-Entrena et al 2014	Soil Conservation (Erosion)	Cover Crops
Lioutas & Charatsari 2018	Sustainability	Various
Manson et al 2016	Climate Change	Rotational Grazing
Juntunen et al 2019	Climate Change	Environmentally Adaptive Practices
Rochecouste et al 2015	Climate Change	Conservation Agriculture (list of many BMPs)

3.2 The Methods used in the articles reviewed.

Reference study	Number of farmer participants	Number of studies in reviews	Methods	Data analysis method used
Niles 2019	n/a	36	literature review of 36 articles	Qualitative systemic review
Baumgart-Getz et al 2012	n/a	46	summary of 46 articles	Quantitative summary
Boz 2018	141	n/a	surveys and interviews	Statistical Package for the Social Sciences software
Ranjan et al 2019	n/a	49	Systemic review of 49 articles	Qualitative systemic review; NVIVO
Mishra et al 2018	230	n/a	surveys	Negative binomial regression
Daxini et al 2019	1009	n/a	surveys	Structural Equation Modeling statistics (SEM)
Zimmerman et al 2019	18	n/a	interviews	Qualitative using NVIVO
Zhang et al 2016	2540	n/a	surveys	Statistical logit model and latent class model
Garbach & Long 2017	109	n/a	surveys	Quantitative using R statistical software
Barreiro-Hurle et al 2010	300	n/a	surveys	Micro-economic modeling
Small 2016	1564	n/a	surveys	STATA statistical package
Ticehurst 2011	503	n/a	surveys	Bayesian Networks
Rodriguez-Entrena et al 2014	232	n/a	interviews	Structural Equation Modeling statistics (SEM)
Lioutas & Charatsari 2018	489	n/a	surveys	Pierson's Correlation statistics
Manson et al 2016	53	n/a	interviews and a case study	Qualitative using NVIVO
Juntunen et al 2019	19	n/a	interviews	Consensual Qualitative Research (CQR)
Rochecouste et al 2015	31	n/a	interviews	Qualitative Causal Loop Diagrams (CLD)
TOTAL:	7238	131		

3.3 The conceptual framework of BMP adoption from Liu et al (2018)

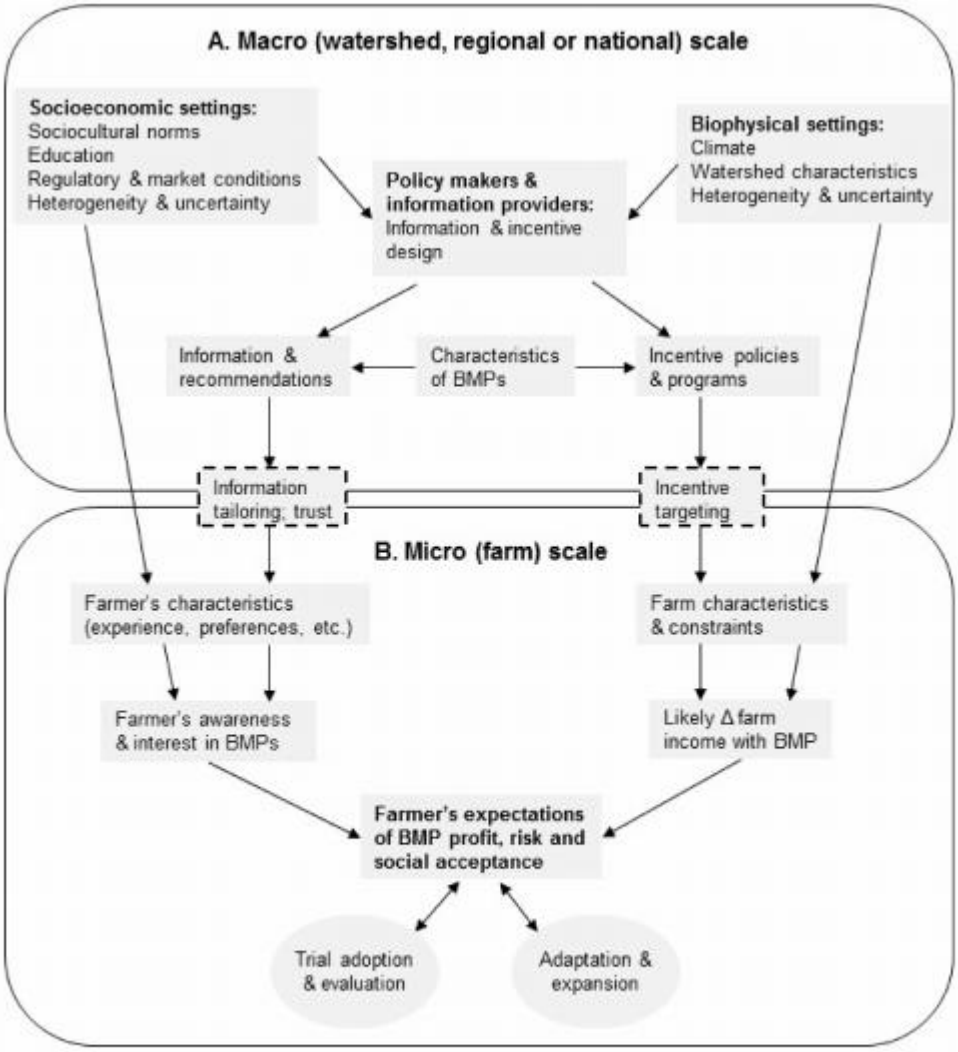

Figure 2. Revised conceptual framework of BMP adoption. Boxes and arrows denote influences; rounded boxes denote scales; ovals represent actions related to BMP adoption; dashed boxes denote elements that may or may not be present.