Technical report: overview of web mapping technologies and vector tile data for an outcome-based web application

RESAS1.2.4 Objective 3 [Deliverable: D7]

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Executive summary

As part of the Scottish Government Strategic Research Programme project 'Assessment of the effectiveness of interventions to achieve water policy objectives (RESAS 1.2.4 Objective 3)', stakeholders have highlighted their need for approaches to aid the spatial targeting of land and water management actions e.g. Scottish Rural Development Programme options for one or more outcomes. Here we provide an overview of the current state of JavaScript[1] web mapping[2] libraries[3] that could be used to aid spatial targeting of land and water management interventions.

In June, a range of stakeholders were asked for feedback on the draft user stories[4]. We received feedback from three colleagues, all of whom were supportive of our approach. A national park representative stressed the importance of the user story related to spatial location of interventions.

The audience for this report is likely to be colleagues with a technical interest in understanding what web mapping options are available for producing web and mobile applications. We provide an overview of six main web mapping libraries structured by: links to resources; background and status; what is needed to add a map on a webpage; how to access draw functionality e.g. select where to place a riparian buffer strip; does it support vector tiles; how to add GeoJSON data; can it be used off-line; and what additional functionality is available (Table 1). A list of vector tile providers is also included.

Table.1 Assessment of web mapping libraries included in this report

Name	License	Use[A]	Support[B]	Draw function	Vector	Off-line
Google Maps	Restrictive	High	High	External	Y	N
Leaflet	Open	High	Medium	External	Plugin	Y
OpenLayers	Open	Medium	Medium	Internal	Y	Y
Mapbox GL	Open	High	High	External	Y	Y
Esri ArcGIS API JS	Restrictive	Unclear	High	Internal	Y	Maybe
GeoJS	Open	Low	Medium	Internal	Y	Y

[A] High use when evidence of wide spread use and a large user base. Medium use when evidence of lower usage and a smaller user base. Low use when evidence of low use e.g. NPM or lack of questions asked on the Web.

[B] High support when excellent documentation, many examples and a large user base. Medium support when one or more of: less well documented code, fewer examples (and not explained) and a smaller user base. Low support when evidence of poorly documented code and fewer examples (and not explained).

When deciding what web mapping library to use, you need to consider: what exactly you are trying to produce e.g. what functionality is required (and by whom); will the web page be freely and publically available or not; what development requirements do you have e.g. existing knowledge, preferences or business requirements for a particular provider or type of license; what budget do you have; and how well documented and supported is a particular web mapping library.

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[1] https://developer.mozilla.org/bm/docs/Web/JavaScript
[2] https://en.wikipedia.org/wiki/Web_mapping
[3] https://en.wikipedia.org/wiki/Library_(computing)
[4] https://en.wikipedia.org/wiki/User_story

1. Introduction

As part of the Scottish Government Strategic Research Programme (SRP) project 'Assessment of the effectiveness of interventions to achieve water policy objectives (RESAS 1.2.4 Objective 3)', stakeholders have highlighted their need for approaches to aid the spatial targeting of land and water management actions e.g. Scottish Rural Development Programme (SRDP) options for one or more environmental outcomes (workshop report (Macleod and Hewitt, 2017)).

In developing our Facilitated Outcome-based Land Management (FOLM) web application to aid land manager decision-making for multiple outcomes, we provide an overview of the current state of web mapping[5] libraries that could be used to aid spatial targeting of land and water management interventions. The importance of web maps for sharing information with a wide range of stakeholders was illustrated in a recent keynote lecture[6] by Jack Dangermond (President of ESRI[7]; a company that provides geographic information systems[8]): who said that web maps provide a common language to enable engagement with everyone. In support of this statement, you just need to think how familiar most people are with searching for a location or directions on Google Maps[9].

This technical report is an update to an earlier report (Macleod and Hewitt, 2018), and is focussed on: summarising stakeholder feedback related to spatial targeting, provide an overview of options for web mapping libraries based on our requirements. The audience for this report is likely to be colleagues with a technical interest in understanding what web mapping options are available for producing web and mobile applications. Specifically, the main options for adding a map and related functionality to a web page, using a small amount of JavaScript[10] code in a standard single page HTML[11] template.

2. Stakeholder needs for web mapping functionality

A key message from stakeholders has been to address their need to view and interact with spatial information about potential land and water management actions (Macleod and Hewitt, 2017) (Table 1). In June, a range of stakeholders were asked for feedback on the draft user stories[12] (see example in Table 1). We received feedback from three colleagues, all of whom were supportive of our approach. A national park representative stressed the importance of the user story in Table 1, highlighting the need for spatial targeting of funding for public benefits. They suggested that it would be useful for land managers to be able to see if they were more likely to gain subsidies in certain locations. He went on to say he thought the user story format was useful.

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[5] https://en.wikipedia.org/wiki/Web_mapping
[6] https://www.youtube.com/watch?v=sMO02fT9RSU&t=51s
[7] https://www.esri.com/en-us/home
[8] https://www.esri.com/en-us/what-is-gis/overview
[9] https://www.google.com/maps
[10] https://developer.mozilla.org/bm/docs/Web/JavaScript
[11] https://developer.mozilla.org/en-US/docs/Glossary/HTML
[12] https://en.wikipedia.org/wiki/User_story

Table 1. Stakeholder need for spatial management information from interviews and workshop

Prioritised needs[1]	Justifications from the stakeholder interviews	Draft user stories
Spatial location of interventions	"have potential for multiple benefits for flooding, soil erosion, all of these only if they are put in the right place" "in terms of diffuse pollution measures, they need to be in the right place for them to be effective"	As a land manager, I want to see the spatial location of interventions, so that I can decide where to implement 'water margins in arable fields' SRDP AECS management option.

3. Implementing 'Spatial location of interventions' user story

The purpose of these sections is to provide an overview of web mapping libraries available for enabling the spatial location of interventions to be included in a web application.

3.1 Comparing web mapping libraries

Since Google Maps was launched in 2005[13], software options for web mapping have increased, including the range of software/service providers and the features/functionality each web mapping provider offers. In this section, we present an overview of the current state of options available for adding spatial mapping functionality to a web page. In addition to covering where to find more information on each of these options, we illustrate specific functionality related to our application: these are how to add draw functionality i.e. providing a graphical interface/button for a user to be able to select an area on a map e.g. potential location of a riparian buffer strip, adding GeoJSON[14] data, their support for vector tiles[15], and ability to be used off-line (Table 2).

Table 2. List of web mapping libraries/technologies included in this report

Name	License	Use[A]	Support[B]	Draw function	Vector	Off-line
Google Maps	Restrictive	High	High	External	Y	N
Leaflet	Open	High	Medium	External	Plugin	Y
OpenLayers	Open	Medium	Medium	Internal	Y	Y
Mapbox GL	Open	High	High	External	Y	Y
Esri ArcGIS API JS	Restrictive	Unclear	High	Internal	Y	Maybe
GeoJS	Open	Low	Medium	Internal	Y	Y

[A] High use when evidence of wide spread use and a large user base. Medium use when evidence of lower usage and a smaller user base. Low use when evidence of low use e.g. NPM or lack of questions asked on the Web.
[B] High support when excellent documentation, many examples and a large user base. Medium support when one or more of: less well documented code, fewer examples (and not explained) and a smaller user base. Low support when evidence of poorly documented code and fewer examples (and not explained).

Traditionally web mapping libraries e.g. Google Maps have primarily been based on providing data as image based map tiles i.e. raster format[16]. Vector tiles store chunks of vector data, instead of storing a map image; this means they can efficiently separate data styling e.g. how a feature is

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[13] https://web.archive.org/web/20160406123606/http://www.google.co.uk/about/company/history/#2005
[14] http://geojson.org/
[15] https://en.wikipedia.org/wiki/Vector_tiles
[16] https://www.mapbox.com/help/define-raster/

presented on a map, from data coordinates and attributes e.g. where it is located. They have advantages over earlier technologies/data formats including raster tiles: for example, vector tiles are smaller/quicker to download, and can easily be customised by anyone e.g. change colour of forested areas without rebuilding every raster tile containing forested areas.

When deciding what web mapping library to use you need to consider: what exactly you are trying to produce e.g. what functionality is required (and by whom); will the web page be freely and publically available or not; what development requirements do you have e.g. existing knowledge, preference or business requirement for a particular provider or type of license; what budget do you have; and how well documented and supported is a particular web mapping library.

3.1.1 Google Maps

3.1.1.1 Links to resources
Table 3. Links to resources about how to use Google Maps

Resources	Web page
Introduction/ overview	https://cloud.google.com/maps-platform/maps/
Documentation	https://developers.google.com/maps/documentation/javascript/tutorial
Examples	https://developers.google.com/maps/documentation/javascript/examples/
Tutorials/ workshop	https://developers.google.com/maps/documentation/javascript/tutorial
Code*	Not available
Release notes/ changelog	https://developers.google.com/maps/documentation/javascript/releases
Licensing	https://cloud.google.com/maps-platform/terms/
Support	https://developers.google.com/maps/support/
Drawling functionality	https://developers.google.com/maps/documentation/javascript/drawinglayer
Other useful resources	Google Developers Geocasts videos https://www.youtube.com/playlist?list=PLOU2XLYxmsIJ8G3nWqLHBhGEY4WmMoZCj

*If open source, then often the code is available on a site like Github.

3.1.1.2 Background and status
Google Maps was launched in 2005 following Google's acquisition of Where 2 Technologies; since then they have extended their map related services to include navigation and search[17]. Recently, Google announced they were revising their existing 18 APIs[18] related to Google Maps into three main products: Maps, Routes and Places[19]. This followed on from an announcement in 2016, that they would stop supporting keyless[20] usage in June 2018 i.e. you would need an API key to use their Maps JavaScript API[21]. The Maps JavaScript API lets you customize maps with your own content and imagery for display on web pages and mobile devices, and includes four basic map types (roadmap, satellite, hybrid, and terrain)- which you can modify using layers and styles, controls and events, and various services and libraries (Table 3).

3.1.1.3 What is needed to add a map on a, free and publically available, webpage?
An introduction to the Maps JavaScript API provides a step by step guide to the code required and guidance on troubleshooting common errors[22].

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[17] https://en.wikipedia.org/wiki/Google_Maps
[18] https://en.wikipedia.org/wiki/Application_programming_interface
[19] https://cloud.google.com/maps-platform/user-guide/
[20] https://en.wikipedia.org/wiki/Application_programming_interface_key
[21] https://cloud.google.com/maps-platform/user-guide/
[22] https://developers.google.com/maps/documentation/javascript/tutorial

3.1.1.4 How to access draw functionality?

To add additional functionality like providing a graphical interface for users to draw a point, line or polygon requires an additional library to be loaded using the libraries parameter in the URL, as shown here:

```
<script type="text/javascript"
  src="https://maps.googleapis.com/maps/api/js?key=YOUR_API_KEY&libraries=drawing">
</script>
```

Instructions on then how to use the drawing library are clearly set out in the documentation, and including examples[23].

3.1.1.5 Does it support vector tiles?

Google Maps has been able to utilise vector tiles since it was redesigned in 2013[24], these changes were announced at that years Google I/O event[25].

3.1.1.6 How to add GeoJSON data?

Google Maps provides a range of ways to add GeoJSON data to a map; these include using the Google Maps Data layer as a container for geospatial data, as explained here[26]. A Google Maps tutorial on 'Importing Data into Maps' shows how to import GeoJSON from either the same domain or a different domain[27].

3.1.1.7 Can it be used off-line?

Google Maps JavaScript API cannot be used off-line e.g. in a location with poor or no mobile signal.

3.1.1.8 What additional functionality is available?

Google make a range of different language/platform APIs available for different computer languages and platforms e.g. for Python and iOS[28]. The Maps JavaScript API is regularly updated and they recommend most applications use the weekly channel as this contains latest bug fixes and performance improvements[29]. You can specify the weekly channel by loading the Maps JavaScript API with the following script tag:

```
<script async defer
  src="https://maps.googleapis.com/maps/api/js?v=weekly
    &key=YOUR_API_KEY&callback=initMap">
</script>
```

In your application you can specify release channel (weekly or quarterly) or version numbers. You need to use one of the last three quarterly updates; older quarterly updates will no longer be available, and the default channel will be returned.

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[23] https://developers.google.com/maps/documentation/javascript/drawinglayer

[24] https://www.engadget.com/2013/05/15/redesigned-google-maps-hands-on-io-2013/?guccounter=1

[25] https://developers.google.com/events/io/2013/

[26] https://developers.google.com/maps/documentation/javascript/datalayer

[27] https://developers.google.com/maps/documentation/javascript/importing_data

[28] https://github.com/googlemaps/

[29] https://developers.google.com/maps/documentation/javascript/versions

3.1.2 Leaflet

Table 4. Links to resources about how to use Leaflet

Resources	Web page
Introduction/overview	https://leafletjs.com/
Documentation	https://leafletjs.com/reference-versions.html
Examples	https://leafletjs.com/examples.html
Tutorials/workshop	https://leafletjs.com/examples.html
Code*	https://github.com/Leaflet/Leaflet
Release notes/changelog	https://github.com/Leaflet/Leaflet/blob/master/CHANGELOG.md
Licensing	https://github.com/Leaflet/Leaflet/blob/master/LICENSE
Support	FAQ https://github.com/Leaflet/Leaflet/blob/master/FAQ.md StackOverflow https://stackoverflow.com/questions/tagged/leaflet
Drawing functionality	Leaflet.Draw https://github.com/Leaflet/Leaflet.draw Leaflet.Editable https://github.com/Leaflet/Leaflet.Editable
Other useful resources	NPM page https://www.npmjs.com/package/leaflet Bundlephobia https://bundlephobia.com/result?p=leaflet@1.3.4

*If open source, then often the code is available on a site like Github.

3.1.2.2 Background and status

Leaflet is an open-source library for mobile-friendly interactive maps that is designed with simplicity, performance and usability in mind. It aims to make the 'basic things work perfectly', whilst being a small library (about 39 KB) (Table 4). Leaflet was first released in 2011 by Vladimir Agafonkin, who then joined Mapbox in 2013, and he is still closely involved in developing Leaflet[30]. It is actively maintained, with over 22,000 stars and over 580 contributors on its Github repository[31]. Leaflet downloads from NPM[32] have doubled over the past year to about 130,000 a week[33].

3.1.2.3 What is needed to add a map on a, free and publically available, webpage?

Follow the instructions in the quick start guide[34]; this includes the CDN[35] links to the Leaflet.css and leaflet.js files. Leaflet can also be added to an application using NPM (Table 4). You can use any map provider with Leaflet e.g. OpenStreetMap[36].

3.1.2.4 How to access draw functionality?

There are a range of plugins to add functionality to Leaflet[37]. Two of the main ones to add draw functionality are Leaflet.draw[38] and Leaflet.Editable[39] (Tables 4 and 5). A comparison of their NPM

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[30] https://en.wikipedia.org/wiki/Leaflet_(software)

[31] https://github.com/Leaflet/Leaflet

[32] NPM is package manager for JavaScript

[33] https://www.npmtrends.com/leaflet

[34] https://leafletjs.com/examples/quick-start/

[35] CDNs (Content Delivery Network) are used to delivery stylesheets and JavaScript files
https://developer.mozilla.org/en-US/docs/Glossary/CDN

[36] https://www.openstreetmap.org/#map=5/54.910/-3.432

downloads shows that Leaflet.draw is more widely used[40], and its Github repository has a larger number of contributors (Tables 4 and 5).

Table 5. Leaflet draw libraries

Library	Created	Github stars	Contributors	StackOverflow tagged questions	GIS StackExch tagged questions
Leaflet.draw	Jun 2012	1,251	105	180[A]	89[B]
Leaflet.Editable	Aug 2014	277	9	14[C]	5[D]

A https://stackoverflow.com/questions/tagged/leaflet.draw
B https://gis.stackexchange.com/questions/tagged/leaflet-draw
C https://stackoverflow.com/search?q=leaflet.editable
D https://gis.stackexchange.com/search?q=leaflet.editable

3.1.2.5 Does it support vector tiles?

Leaflet developers aim to provide basic mapping features- that do not include vector tiles. There is a Leaflet Plugin Leaflet.VectorGrid[41] to provide this functionality; it is downloaded about 1000 times a week[42] (compared to Leaflet being downloaded over 120,000 times a week). Over the past year there has only been several commits to Leaflet.VectorGrid and the last release, at the time of writing, was in August 2017.

3.1.2.6 How to add GeoJSON data?

One of the Leaflet tutorials[43] is about how to work with GeoJSON data; this makes it clear Leaflet supports all the GeoJSON types. The geojson-vt library[44] can also be used with Leaflet; it is an efficient library for slicing GeoJSON data into vector tiles on the fly. It is maintained by the lead developer of Leaflet (Vladimir Agafonkin), with over 30 commits over the past year and, at the time of writing, the last release[45] was in July 2018.

3.1.2.7 Can it be used off-line?

Leaflet is readily available from NPM and can be used off-line.

3.1.2.8 What additional functionality is available?

Leaflet is designed to excel at providing basic interactive mobile friendly maps, so does not provide many of the features of other libraries. Additional features can often be found in the list of plugins[46]; however, these vary in terms of level of support and documentation.

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[37] https://leafletjs.com/plugins.html
[38] https://leaflet.github.io/Leaflet.draw/docs/leaflet-draw-latest.html
[39] http://leaflet.github.io/Leaflet.Editable/doc/api.html
[40] https://www.npmtrends.com/leaflet-draw-vs-leaflet-editable
[41] https://github.com/Leaflet/Leaflet.VectorGrid
[42] https://www.npmtrends.com/leaflet.vectorgrid
[43] https://leafletjs.com/examples/geojson/
[44] https://github.com/mapbox/geojson-vt
[45] https://github.com/mapbox/geojson-vt/releases
[46] https://leafletjs.com/plugins.html

3.1.3 OpenLayers

3.1.3.1 Links to resources
Table 6. Links to resources about how to use OpenLayers

Resources	Web page
Introduction/overview	http://openlayers.org/ http://openlayers.org/en/latest/doc/quickstart.html
Documentation	http://openlayers.org/en/latest/apidoc/
Examples	http://openlayers.org/en/latest/examples/
Tutorials/workshop	http://openlayers.org/workshop/ http://openlayers.org/en/latest/doc/tutorials/
Code*	https://github.com/openlayers/openlayers
Release notes/changelog	https://github.com/openlayers/openlayers/releases
Licensing	Released under the 2-clause BSD License (also known as the FreeBSD) https://tldrlegal.com/license/bsd-2-clause-license-(freebsd)
Support	FAQs http://openlayers.org/en/latest/doc/faq.html GIS StackExchange tags https://gis.stackexchange.com/questions/tagged/openlayers StackOverflow tags https://stackoverflow.com/questions/tagged/openlayers https://stackoverflow.com/questions/tagged/openlayers-5
Drawing functionality	Examples http://openlayers.org/en/latest/examples/draw-features.html http://openlayers.org/en/latest/examples/draw-and-modify-features.html Workshop section http://openlayers.org/workshop/en/vector/draw.html
Other useful resources	https://www.osgeo.org/projects/openlayers/

*If open source, then often the code is available on a site like Github.

3.1.3.2 Background and status
OpenLayers was originally developed by MetaCarta in 2005; it then became an Open Source Geospatial Foundation project in 2007[47]. In 2014, OpenLayers v3 was released to take advantage of new capabilities of modern browsers e.g. WebGL[48]. In 2017, OpenLayers v4[49] was released to take advantage of changing best practices e.g. semantic versioning [50] and JavaScript modules[51]. Then in 2018, OpenLayers v5[52] was released as a set of JavaScript modules. It is actively maintained by a small group of core developers, with over 4,000 stars and over 200 contributors on its Github repository[53].

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[47] https://en.wikipedia.org/wiki/OpenLayers

[48] https://developer.mozilla.org/en-US/docs/Web/API/WebGL_API

[49] https://github.com/openlayers/openlayers/releases/tag/v4.0.0

[50] https://semver.org/

[51] http://exploringjs.com/es6/ch_modules.html

[52] https://github.com/openlayers/openlayers/releases/tag/v5.0.0

[53] https://github.com/openlayers/openlayers

3.1.3.3 What is needed to add a map on a, free and publically available, webpage?

The quick start page[54] sets out how to put a simple map on a web page, helpfully explaining what each part of the code does. A page on OpenLayer's basic concepts[55] sets out how map, view, source and layer work together in a script to render a map.

3.1.3.4 How to access draw functionality?

OpenLayers is a feature-packed library with an extensive API. However, at the time of writing, the developers are aware that the library is poorly documented compared to other web mapping libraries. The best guidance on adding draw functionality is set out in the workshop[56]- this covers the importing of the 'Draw interaction' and configuring it.

3.1.3.5 Does it support vector tiles?

OpenLayers supports vector tiles and includes a VectorTile type of layer (Table 6). The workshop provides useful guidance on how to add and style vector tiles[57]. The OpenLayers examples include some that use vector tiles; however there is limited accompanying explanation (Table 6).

3.1.3.6 How to add GeoJSON data?

The workshop provides a lesson on how to add, modify and style GeoJSON[58].

3.1.3.7 Can it be used off-line?

OpenLayers is readily available from NPM and can be used off-line.

3.1.3.8 What additional functionality is available?

OpenLayers is considered to have a wide range of functionality, often referred to as a full web GIS. Currently, it is very difficult to assess exactly what functionality it contains, unless you look at the code or dissect the examples (Table 6).

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[54] http://openlayers.org/en/latest/doc/quickstart.html
[55] https://openlayers.org/en/latest/doc/tutorials/concepts.html
[56] https://openlayers.org/workshop/en/vector/draw.html
[57] https://openlayers.org/workshop/en/vectortile/
[58] http://openlayers.org/workshop/en/vector/

3.1.4 Mapbox GL.js

3.1.4.1 Links to resources
Table 7. Links to resources about how to use Mapbox GL.js

Resources	Web page
Introduction/overview	https://www.mapbox.com/help/how-web-apps-work/
Documentation	https://www.mapbox.com/mapbox-gl-js/api/
Examples	https://www.mapbox.com/mapbox-gl-js/example/simple-map/
Tutorials/workshop	https://www.mapbox.com/help/tutorials/#web-apps List of workshop material https://github.com/mapbox/workshops
Code*	https://github.com/mapbox/mapbox-gl-js
Release notes/changelog	https://github.com/mapbox/mapbox-gl-js/releases
Licensing	https://github.com/mapbox/mapbox-gl-js/blob/master/LICENSE.txt
Support	GIS StackExchange tags https://gis.stackexchange.com/questions/tagged/mapbox https://gis.stackexchange.com/questions/tagged/mapbox-gl-js https://gis.stackexchange.com/questions/tagged/mapbox-gl Stackoverflow tags https://stackoverflow.com/questions/tagged/mapbox https://stackoverflow.com/questions/tagged/mapbox-gl-js https://stackoverflow.com/questions/tagged/mapbox-gl
Drawing functionality	https://www.mapbox.com/mapbox-gl-js/example/mapbox-gl-draw/ https://github.com/mapbox/mapbox-gl-draw
Other useful resources	Blog (covering a range of Mapbox products and services) https://blog.mapbox.com/

*If open source, then often the code is available on a site like Github.

3.1.4.2 Background and status
Mapbox[59] released the first version (v0.0.1) of Mapbox GL.js in early 2014. This followed on from their focus on Mapbox.js, which was released as a Leaflet plugin[60]. Mapbox.js currently receives less support, from Mapbox and the wider web mapping community, with only about 40 commits over the past year, and the last release (v.3.1.1; at time of writing) was in May 2017. Mapbox.js is still downloaded several thousand times a week but this has decreased by over 50% over the past year, and is an order of magnitude less than the weekly downloads of Mapbox GL.js[61].

Mapbox GL.js is based on Leaflet, and it uses WebGL[62] to render interactive maps from vector tiles[63]. It is actively maintained with over 2,700 stars and over 1,000 commits over the past year from over 15 active developers (with at least 10 commits each) and over 200 contributors on its Github

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[59] https://www.mapbox.com/
[60] https://blog.mapbox.com/announcing-mapbox-js-1-0-with-leaflet-b424decceaf6
[61] https://www.npmtrends.com/mapbox-gl-vs-mapbox.js
[62] https://developer.mozilla.org/en-US/docs/Web/API/WebGL_API
[63] https://www.mapbox.com/mapbox-gl-js/api/

repository[64]. It is actively supported by Mapbox[65], a leading open source location data company that has grown rapidly since its origin in 2010.

3.1.4.3 What is needed to add a map on a, free and publically available, webpage?

Mapbox provide an excellent guide to how web apps work[66]; this covers Mapbox.js and Mapbox GL.js. In a blog article they provide a quickstart guide to using Mapbox GL.js[67]. Mapbox make Mapbox GL.js freely available, however to use their tilesets you need an API key. They provide a 'pay as you go' plan that is free to start with: this includes up to 50,000 map views on web apps per month, and generous 50GB tileset storage and 5GB dataset storage. For paid websites and websites with restricted access, then a commercial license is required.

3.1.4.4 How to access draw functionality?

Though the draw functionality is in a separate Github repository[68] to the main Mapbox GL.js code, it seems to be well maintained by Mapbox and other developers e.g. issues are still being closed.

3.1.4.5 Does it support vector tiles?

Mapbox released an open standard for vector tiles in 2014[69] which was widely adopted e.g. by Esri[70]. Mapbox GL.js was designed to be used with vector tiles (Table 7).

3.1.4.6 How to add GeoJSON data?

There are multiple ways to add GeoJSON data, these include adding GeoJSON data to Mapbox Studio[71] to create a tileset[72] as shown in this tutorial[73]. Vladmir Agafonkin created an efficient way to slice up GeoJSON data into vector tiles on the fly i.e. on the browser without a server[74].

3.1.4.7 Can it be used off-line?

Mapbox GL.js is readily available from NPM and can be used off-line (Table 7).

3.1.4.8 What additional functionality is available?

Mapbox have produced a wide range of tools focussed on greater use of vector tiles on a range of platforms, exampled range from Mapbox studio to Mapbox GL APIs for mobile platforms. There are clear and structured lists of plugins, which are maintained by Mapbox[75]. In addition, there is a well written blog (covering a range of location products and services)[76].

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[64] https://github.com/mapbox/mapbox-gl-js

[65] https://www.mapbox.com/

[66] https://www.mapbox.com/help/how-web-apps-work/

[67] https://blog.mapbox.com/quickstart-guide-to-mapbox-javascript-api-4b376c68dd46

[68] https://www.mapbox.com/mapbox-gl-js/example/mapbox-gl-draw/

[69] https://github.com/mapbox/vector-tile-spec

[70] https://blog.mapbox.com/mapbox-vector-tile-specification-adopted-by-esri-14138105872f

[71] https://www.mapbox.com/mapbox-studio/

[72] https://www.mapbox.com/help/define-tileset/

[73] https://www.mapbox.com/help/choropleth-studio-gl-pt-1/

[74] https://blog.mapbox.com/rendering-big-geodata-on-the-fly-with-geojson-vt-4e4d2a5dd1f2

[75] https://www.mapbox.com/mapbox-gl-js/plugins/

[76] https://blog.mapbox.com/

3.1.5 Esri ArcGIS API for JavaScript

3.1.5.1 Links to resources
Table 8. Links to resources about how to use ArcGIS API for JavaScript

Resources	Web page
Introduction/ overview	https://developers.arcgis.com/javascript/latest/guide/index.html
Documentation	https://developers.arcgis.com/javascript/latest/api-reference/index.html
Examples	https://developers.arcgis.com/javascript/latest/sample-code/index.html
Tutorials/ workshop	https://developers.arcgis.com/javascript/latest/sample-code/intro-layers/index.html https://developers.arcgis.com/labs/?product=JavaScript&topic=any
Code*	https://developers.arcgis.com/javascript/latest/guide/get-api/index.html
Release notes/ changelog	https://developers.arcgis.com/javascript/latest/guide/release-notes/index.html
Licensing	Strict/restrictive license
Support	GeoNet https://community.esri.com/community/developers/web-developers/arcgis-api-for-javascript
Drawing functionality	https://developers.arcgis.com/javascript/latest/sample-code/sketch-geometries/index.html
Other useful resources	Esri blog filtered for ArcGIS API for JS https://www.esri.com/arcgis-blog/?s=#&products=js-api-arcgis Esri videos https://www.youtube.com/channel/UC_yE3TatdZKAXvt_TzGJ6mw/search?query=ArcGIS+API+for+JavaScript+tech+sessions+2018

*If open source, then often the code is available on a site like Github.

3.1.5.2 Background and status
Esri has been a long term provider of desktop and server based GIS. They describe their ArcGIS API for JavaScript (ArcGIS.js) as their key product for building web applications to visualize, map, edit and analyse geographic data (Table 8). The API is built using Dojo[77] (a long established JavaScript framework, which was popular for enterprise applications); there is guidance on integrating the API with other JS frameworks[78]. Esri released version 4.0[79] in May 2016 introducing a lot of new capabilities e.g. 3D support. They are gradually adding most of the 3.x capabilities into 4.x versions, as summarised here[80]. They provide a useful guide and comparison between versions 3.x and 4.x[81]. Esri are putting a lot of effort into improving the ArcGIS.js, and for future commitment you just need to watch Jack Dangermond (Esri President) talk about the importance of web mapping[82].

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[77] https://dojotoolkit.org/

[78] https://developers.arcgis.com/javascript/latest/guide/using-frameworks/index.html

[79] https://developers.arcgis.com/javascript/latest/guide/release-notes/4.0/index.html

[80] https://developers.arcgis.com/javascript/latest/guide/functionality-matrix/index.html

[81] https://developers.arcgis.com/javascript/latest/guide/choose-version/index.html

[82] https://www.youtube.com/watch?v=sMO02fT9RSU&t=51s

3.1.5.3 What is needed to add a map on a, free and publically available, webpage?

One of Esri's ArcGIS.js strengths is the level of guidance and information, for example the examples are more like individual tutorials and just one click takes you to a working sandbox that you can explore and modify (Table 8). There are also developer labs that take you through a wide range of tasks, these guide you through the steps and provide links to a blank code pen for you to use and a completed one to compare your code with. To create a map then there may be a need to sign into ArcGIS for developers[83] -this is where you can create and manage app, create and manage layers and view credit usage.

3.1.5.4 How to access draw functionality?

ArcGIS.js has a lot of built in functionality including drawing, this is demonstrated in this illustrated example[84].

3.1.5.5 Does it support vector tiles?

Esri have long supported vector tiles, with the VectorTileLayer[85] class being available since version 4.0. A basic example is provided by Esri[86].

3.1.5.6 How to add GeoJSON data?

There is a wide range of ways to add GeoJSON data, including within a script and loading it externally[87].

3.1.5.7 Can it be used off-line?

ArcGIS JavaScript.js can be used off-line but it is a very large file (~ 40 MB).

3.1.5.8 What additional functionality is available?

Esri's ArcGIS.js is a feature rich GIS API with a large number of analysis and location services. There is guidance[88] how to work with the wider ArcGIS platform; this includes ArcGIS Online[89], which is a cloud-based collaborative content management system for maps, data and apps. ArcGIS.js can be used to access and edit existing content and create new content.

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[83] https://developers.arcgis.com/sign-in?redirect_uri=%2Fdownloads%2Fapis-and-sdks%3Fproduct%3Djavascript

[84] https://developers.arcgis.com/javascript/latest/sample-code/sketch-geometries/index.html

[85] https://developers.arcgis.com/javascript/latest/api-reference/esri-layers-VectorTileLayer.html

[86] https://developers.arcgis.com/javascript/latest/sample-code/layers-vectortilelayer/index.html

[87] https://developers.arcgis.com/javascript/latest/sample-code/layers-featurelayer-collection/index.html

[88] https://developers.arcgis.com/javascript/latest/guide/working-with-platform/index.html

[89] https://doc.arcgis.com/en/arcgis-online/reference/what-is-agol.htm

3.1.6 GeoJS

3.1.6.1 Links to resources
Table 9. Links to resources about how to use GeoJS

Resources	Web page
Introduction/overview	http://opengeoscience.github.io/geojs/
Documentation	https://geojs.readthedocs.io/en/latest/
	http://opengeoscience.github.io/geojs/apidocs/
Examples	http://opengeoscience.github.io/geojs/examples/
Tutorials/workshop	http://opengeoscience.github.io/geojs/tutorials/
Code*	https://github.com/OpenGeoscience/geojs
Release notes/changelog	https://github.com/OpenGeoscience/geojs/releases
Licensing	Licensed under the Apache License 2.0
Support	Very few Q&A on https://gis.stackexchange.com/ or
	https://stackoverflow.com/
Drawing functionality	http://opengeoscience.github.io/geojs/examples/annotations/
Other useful resources	Kitware Blog
	https://blog.kitware.com/?s=geojs
	NPM page
	https://www.npmjs.com/package/geojs

*If open source, then often the code is available on a site like Github.

3.1.6.2 Background and status
GeoJS enables a wide range of geospatial visualizations for large datasets using WebGL (Table 9). GeoJS aims for high-performance visualization and interactive data exploration of scientific and geospatial location aware datasets[90].It is a long standing open source project, supported by a core group of developers who mainly work for Kitware[91] -an open source software company supporting open and reproducible science. It is under active development with several well documented releases over the past year (version 0.12.3 to 0.18.1).

3.1.6.3 What is needed to add a map on a, free and publically available, webpage?
The GeoJS tutorial page[92] suggests the simple map tutorial is a good place to start learning how to use GeoJS. In the tutorial it takes you through each of the key steps of setting up the HTML, adding the CSS and JavaScript.

3.1.6.4 How to access draw functionality?
The 'annotation' example[93] sets out how to add draw functionality; this example does involve quite a lot of code including JQuery[94], another JavaScript library which is widely used to manipulate HTML documents.

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[90] https://github.com/OpenGeoscience/geojs

[91] https://www.kitware.com/about/

[92] http://opengeoscience.github.io/geojs/tutorials/

[93] http://opengeoscience.github.io/geojs/examples/annotations/docs/main.html

[94]

3.1.6.5 Does it support vector tiles?

It is unclear if GeoJS supports vector tiles, though since it uses WebGL it should. The only reference I could find was in a Github issue about supporting the vector tile spec[95].

3.1.6.6 How to add GeoJSON data?

There are several ways to add GeoJSON, with several tutorials showing how to add point[96] data in a script or reading in a GeoJSON file[97].

3.1.6.7 Can it be used off-line?

GeoJS is readily available from NPM and can be used off-line (Table 9).

3.1.6.8 What additional functionality is available?

The company behind GeoJS (Kitware) is a long term provider of open source visualisation software. It is possible to add interactive features based on D3[98].

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[95] https://github.com/OpenGeoscience/geojs/issues/344
[96] http://opengeoscience.github.io/geojs/tutorials/simple_point/
[97] http://opengeoscience.github.io/geojs/tutorials/choropleth/
[98] https://d3js.org/

3.2 Discussion

The above overview (including Table 2) is designed to offer insights into the relative merits of the web mapping options; specifically in the context of the functionality we have explored in developing our Facilitated Outcome-based Land Management (FOLM) web application. This synopsis is not meant to be 100% complete, and the development status of these web mapping libraries is likely to change rapidly. Though there are similarities between these web mapping libraries e.g. how added to an HTML document, their APIs and key components differ.

As said above (Section 3.1), depending what you are trying to do will determine what libraries you consider using. In our case, we need a library that provides the required drawing and vector functionality, which is well documented and supported and can be used offline; based on these requirements we are currently using Mapbox GL.js. As I have written this short review, I have become more impressive that the Mapbox GL.js code is on Github and Mapbox provide excellent and generous support for vector tiles through Mapbox Studio, whereas the Google Maps code is not available and the Esri ArcGIS.js code though, well documented and supported, cannot be modified and is extremely large for a web application (though I have not tested the final size in a production setting). In Appendix 1, there is a list of providers of vector tile, and notes on which web mapping libraries they can be used with.

As a caveat there are other web mapping providers that offer limited information in English e.g. Baidu Maps[99] and Yandex.Maps[100]. There is also a wider range of ways to add maps to web applications using third party software, for example the excellent R Shiny[101] and Jupyter notebooks[102], the later can be used with dozens of computer languages.

4. Next steps

The next steps are to continue developing our prototype based on Mapbox GL.js. We will present this at a stakeholder focussed land use conference[103] in November.

Acknowledgements

References

MACLEOD, C. J. A. & HEWITT, R. 2017. *Workshop summary: developing an outcome-based approach for understanding the effectiveness of interventions in catchments for multiple benefits*. The James Hutton Institute.

MACLEOD, C. J. A. & HEWITT, R. 2018. *Technical report: progress with developing an outcome-based web application*. The James Hutton Institute.

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[99] http://lbsyun.baidu.com/index.php?title=%E9%A6%96%E9%A1%B5

[100] https://cyberleninka.ru/article/n/comparison-of-javascript-libraries-for-web-cartography

[101] http://shiny.rstudio.com/

[102] http://jupyter.org/

[103] https://www.sruc.ac.uk/info/120470/land_use_conference

Appendix 1. List of vector tile providers

There are an increasing number of options for how you access vector tiles; aspects to consider include the content of the tiles themselves, restrictions on their use, and their cost of use. Also the choice of vector tiles is often linked to which web mapping library you are planning to use; for example, only Google Map tiles can be used with the Google Map API. Whereas, other web mapping libraries e.g. Leaflet are completely agnostic about which source of tiles you use.

Table 10. List of vector tile suppliers

Supplier and notes	Web links
Mapbox Long term provider six default tilesets, including Terrain (RGB-encoded dem).	https://www.mapbox.com/studio/tilesets/
UK Ordnance Survey Recent OS Open Zoomstack trial of a basemap at a national level, right down to street level detail.	https://www.ordnancesurvey.co.uk/business-and-government/products/os-open-zoomstack.html
OpenMapTiles and MapTiler Provide open-source set of eight map styles. MapTiler is a new cloud service based on the OpenMapTiles.	https://openmaptiles.org/ https://www.maptiler.com/
Thunderforest Provide nine tilesets including widely used OpenCyleMap.	https://www.thunderforest.com/
Esri Since 2015 they have provided vector basemaps (currently 8 tilesets).	https://www.arcgis.com/home/group.html?id=30de8da907d240a0bccd5ad3ff25ef4a#overview
Google You need to use one of four types of tilesets associated with the Maps JavaScript API.	https://developers.google.com/maps/documentation/javascript/maptypes
OpenStreetMap The main provider of free map tiles that are used by many other providers as the basis of their tiles. Since their servers are run entirely on donated resources, there are strict requirements on their use.	https://wiki.openstreetmap.org/wiki/Tiles https://operations.osmfoundation.org/policies/tiles/
OpenTopoMap Is a free topographic map from data in OpenStreetMap and STRM[104] elevation. OpenTopoMap is licensed under CC-BY-SA. This means that they may be used free of charge, as long as attribution always takes place.	https://opentopomap.org/about

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[104] https://en.wikipedia.org/wiki/Shuttle_Radar_Topography_Mission